CONCEPTS OF SCIENCE

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R. G. Cull W. A. Drake

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Preface

This is the third book of the *Concepts of Science* series. It has been prepared to provide a course in science for Year 9.

All four books of the series follow the same format. Each chapter contains:

- a complete unit of information enabling students to find answers to questions raised in their science courses
- detailed descriptions of a number of carefully chosen experiments related to the subject of the chapter
- a summary of facts
- a spelling list
- brief descriptions of some additional experiments
- a list of questions extending from the information presented in the chapter (Questions demanding further research by the student are marked (R).)
- an objective test designed to tell the student how well he has understood the chapter.

In following this format the authors hope that they have produced a book that is easy to use both at school and at home.

R. G. Cull
W. A. Drake

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The authors wish to acknowledge and thank those people who assisted in the preparation of this book. In particular they would like to thank I. Plimer of Macquarie University for much valuable help in the preparation of the geology chapters. As well, they wish to thank J. A. Croft of Macquarie University for making available a number of blue-ringed octopuses. Finally they express their appreciation to A. Torrens for his painstaking work in producing many of the photographs and to Barbara Gurney, who prepared the illustrations.

1

Volcanoes and volcanic rocks

Volcanic eruptions have been observed throughout human history. One of the most devastating occurred in 1883 when the volcanic island of Krakatoa blew up in a series of gigantic explosions. Only one-third of the island remained and the disturbance of the sea bed produced immense waves along the coasts of Java and Sumatra. These waves drowned some 36 000 people.

Many volcanoes are active throughout the world today. These give geologists clues about the nature of the material in the earth's crust. They also provide an opportunity to observe directly the formation of igneous rocks from the liquid state.

In this chapter we will study some of the features of volcanic landscapes and the types of volcanic rocks found there.

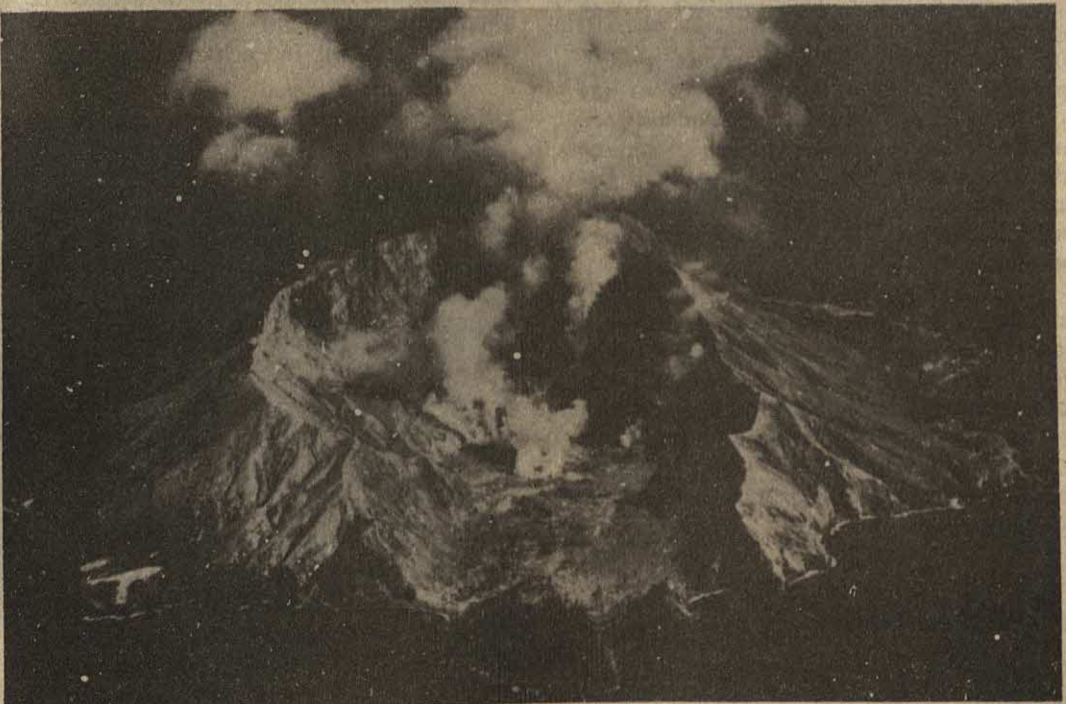


Figure 1.1: White Island — an active volcano off the Bay of Plenty, New Zealand. The huge hole would have been the result of an explosive eruption. (Photo courtesy New Zealand Information Service)

Formation of volcanoes

Volcanoes are natural openings in the earth's crust. They are connected by vents to deep underground caverns, which are filled with liquid rock. Periodically they erupt and material from the vent builds up a cone. The shape of the cone depends on the nature of the material coming from the volcano. (See figures 1.4 and 1.7.)

Scientists have from time to time put forward theories about the source of the heat that melts the rock. It was first believed that it was part of the heat the earth had when it was first formed. Then it was thought it was heat due to friction. This friction was caused as the crust of the earth shrank and moved over the rocks underneath. Scientists have ruled out both these theories, as neither of them explains the enormous amount of liquid rock in the crust. They now generally agree that the heat is due to the radioactivity of rocks in the earth's interior.

The rocks in the interior, although very hot, may not be molten because of the great pressure on them. However, sometimes this pressure is relieved by movement of the rocks above; when this happens the hot rock may melt to form large masses of molten material called *magma*. This magma may be squeezed through the crust to the surface, melting large blocks of rock that then become part of it.

When the liquid rock reaches the surface it is called *lava*. Lava contains less dissolved gas than magma, because gases escape as the liquid gets closer to the surface. If the vent leading to the surface becomes blocked with solid rock, this gas can build up tremendous pressure. This pressure may cause eruptions that are explosive rather than just an outpouring of lava.

Volcanic rocks

Volcanic rocks are formed from either of the following:

- lavas, which erupt quietly from the vent of the volcano
- fragmental rocks, which are thrown out of the vent by violent explosions inside the volcano.

Lavas

Some lavas, like the basalts of the Hawaiian Islands, are very fluid; they are often compared to honey. They may flow eighty kilometres or more before solidifying. Sometimes these basalts have elongated holes or vesicles in them. This structure is due to the escape of gas as the lava solidifies. (See figure 1.2.)

On the other hand, some lavas, like rhyolite, are very viscous. Often they flow only a few metres from the vent before solidifying. Since it is formed from sticky and slow-moving lava, rhyolite often shows flow lines in the solid rock. For the same reason rhyolite lavas often form domes with very steep sides.

Volcanic igneous rocks range from the light-coloured rhyolites to the dark-coloured basalts. The colour difference is due to the different minerals in each of these rocks:

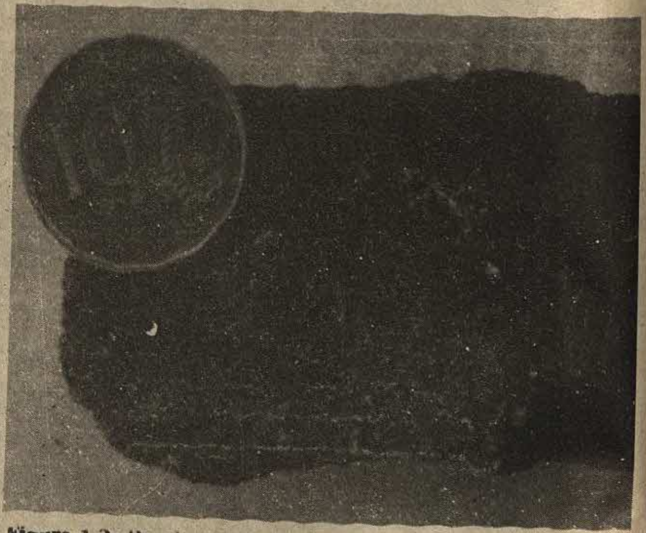


Figure 1.2: Basalt, the commonest of all volcanic rocks. Notice the bubble holes produced by gases trapped in the lava as it solidified. This specimen came from Mount Exmouth, a long flat-topped mountain in the Warrumbungle National Park, New South Wales.

rhyolite contains quartz while basalt contains no quartz. Quartz is silicon dioxide, that is, the oxide of a non-metal. Oxides of non-metals are acidic oxides. For this reason, rhyolite is called an acid rock. Basalt, because it contains no quartz, is called a basic rock.

The light-coloured rocks contain, in addition to silica, a lot of feldspar and a small proportion of ferromagnesian minerals. For this reason, they are sometimes called felsic rocks, "felsic" being a contraction of "feldspar" and "silica". The dark-coloured rocks, on the other hand, contain no silica, a little feldspar and a high proportion of ferromagnesian minerals. They are sometimes called mafic rocks. "Mafic" is a contraction of "magnesium" and "ferric", a word often applied to iron compounds.

These rocks are all very fine-grained, indicating that their lavas cooled and solidified quickly. (See table 1.1.)

Sometimes cracking occurs in solid volcanic rocks. This is due to contraction as they cool. The cracks often join up and form a regular pattern called columnar jointing. The columns formed usually contain five sides, as shown in figure 1.3.

The surface of a lava flow cools more quickly than the remainder. Sometimes lava at the surface sets before crystals have even formed. In this way, volcanic glasses are produced. Table 1.2 describes several types of glassy rock.

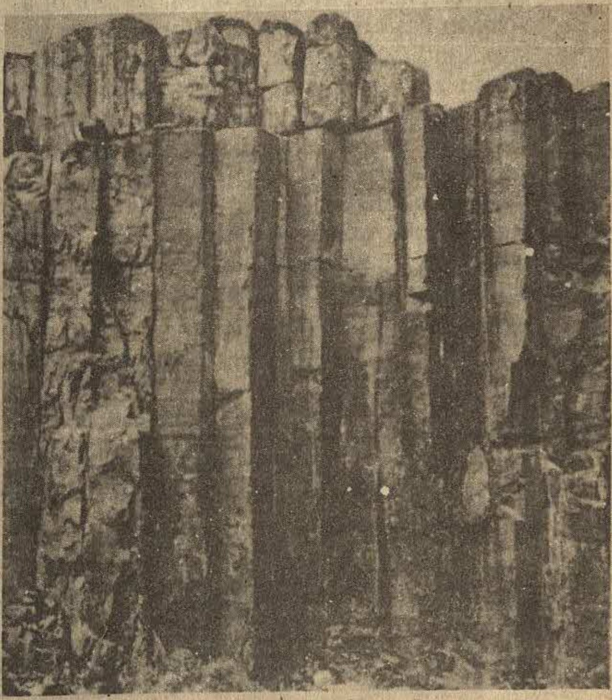


Figure 1.3: Columnar jointing in volcanic rock in a quarry at Kiama, New South Wales. The sides of the columns are well over a metre wide.

Table 1.1: Fine-grained volcanic rocks

Rock	Description	Comments
Basalt	A dark, very fine-grained crystalline rock	Basalt is rich in ferromagnesian minerals. It contains no quartz.
Rhyolite	A light-coloured, very fine-grained crystalline rock. Rhyolite sometimes shows flow lines.	Rhyolite is rich in feldspar and quartz. It contains a very small percentage of ferromagnesian minerals.

Table 1.2: Glassy rocks

Rock	Description	Comments
Obsidian	A black volcanic glass that breaks with a conchoidal fracture	Obsidians are acid in composition.
Pumice	A light-coloured rock that is extremely porous and floats on water	The holes in the rock are gas holes. They are formed by bubbles of steam and gas causing the volcanic glass to froth while it is still viscous.

Fragmental rocks

Some volcanic eruptions are violently explosive. These may occur when the vent of a volcano has been sealed off, for example by lava solidifying in the vent. As the magma within the volcano solidifies, gases escape from it and build up tremendous pressure in the space available to them. This pressure may blow the vent open and eject solid fragments ranging in size from fine dust to huge blocks weighing many tonnes. These fragments may eventually be compressed and cemented to form rocks. Some of these rocks are listed in table 1.3.

Volcanic landscape

Flows

Basaltic lava is very fluid. In some cases it flows out of long fissures in the ground. It may spread for hundreds of kilometres, filling up all the valleys to form thick plateaus of volcanic rock. The basalts of the Deccan Plateau in India are a good example. Basalt floods have occurred in Iceland in recent times. One at Laki in 1783 covered more than 500 square kilometres of ground.

Table 1.3: Volcanic fragmental rocks

Rock	Description	Comments
Tuff	Consists of fine volcanic ash and dust compressed and cemented together	The rock-forming ash and dust may be blown many kilometres by the wind before settling. Tuff may also be formed from this material after it settles in water, or from the hot mud that results when it mixes with rain water.
Volcanic breccia	Consists of larger angular fragments and fine-grained fragments such as ash, cemented together	The wind cannot carry the larger fragments so breccias are found fairly close to a vent.
Volcanic agglomerate	Consists of large blocks of rock and finer-grained fragments, cemented together	Agglomerates are found very close to a vent.

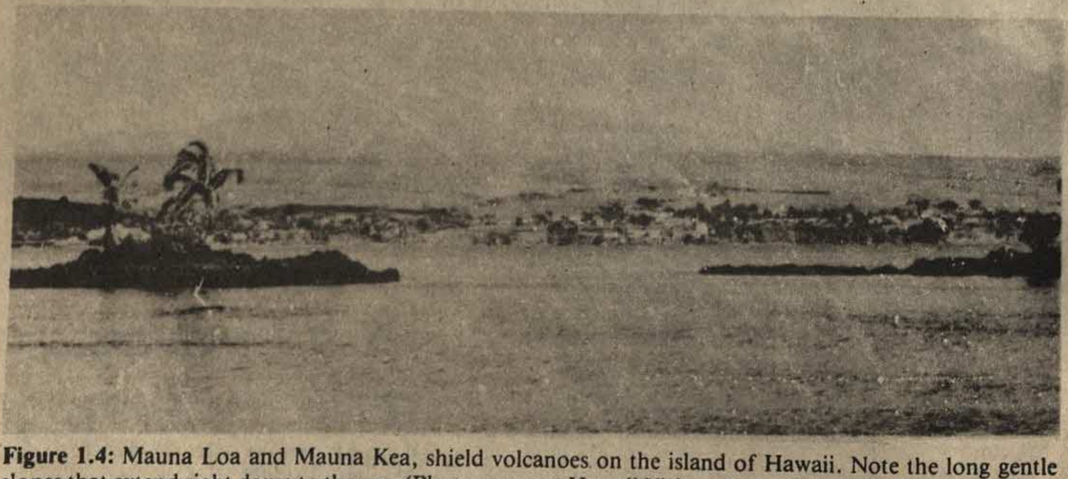


Figure 1.4: Mauna Loa and Mauna Kea, shield volcanoes on the island of Hawaii. Note the long gentle slopes that extend right down to the sea. (Photo courtesy Hawaii Visitors Bureau)

In other cases the lava flows quietly from a central vent. In these cases large volcanoes shaped like huge shields are gradually built up. The island of Hawaii is a good example of a shield. It is an immense mountain with a diameter of nearly 80 kilometres at sea level. It has been built up by two volcanoes, each rising nearly 4300 metres out of the sea. (See figure 1.4.)

Figure 1.5: Mount Banks, in the Blue Mountains of New South Wales. The mountain has a basalt cap that has resisted erosion more than the surrounding country. The basalt was part of a volcanic flow that occurred in Tertiary times, millions of years ago.

Cones

Violent eruptions form cones with steep slopes. This is because the rock fragments ejected from the vent in violent eruptions come to rest at a fairly steep angle — their rough edges help to stop them from slipping. Most eruptions are a mixture of this type and the quiet lava flow type. Figure 1.6 is a diagram of a typical cone formed by mixed eruptions. The alternate layers of fragmental rocks and lava flows indicate successive periods of violent eruptions and quiet flows. Notice the many fractures in the rocks around the central cone.

Craters

Sometimes an eruption is so explosive that it may completely blow the top off a volcano, thus forming a crater. Renewed volcanic activity may build up a smaller cone within the crater, as shown in figure 1.6.

Rabaul Harbour in New Britain is the crater of an old volcano partially filled by the sea. The harbour has several active smaller volcanoes around the rim of the crater. (See figures 1.9 and 1.10.)

The craters of extinct volcanoes are often filled with water to form crater lakes. Blue Lake at Mount Gambier in South Australia is a good example. (See figure 1.11.)

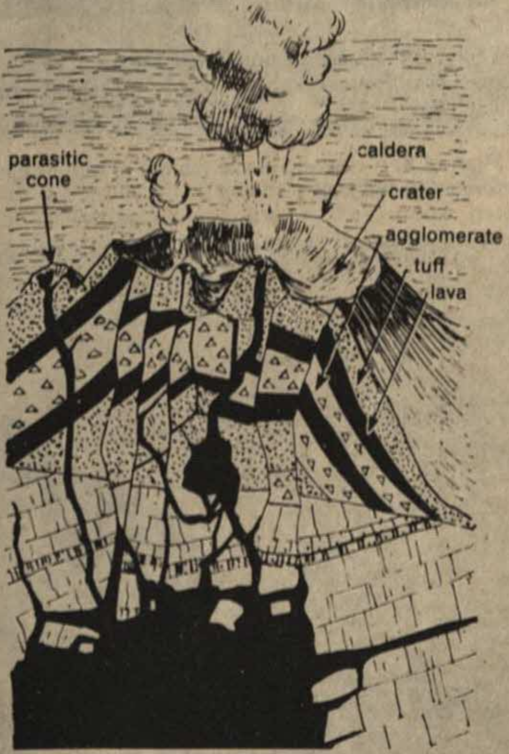


Figure 1.6: A typical cone formed by mixed eruptions.

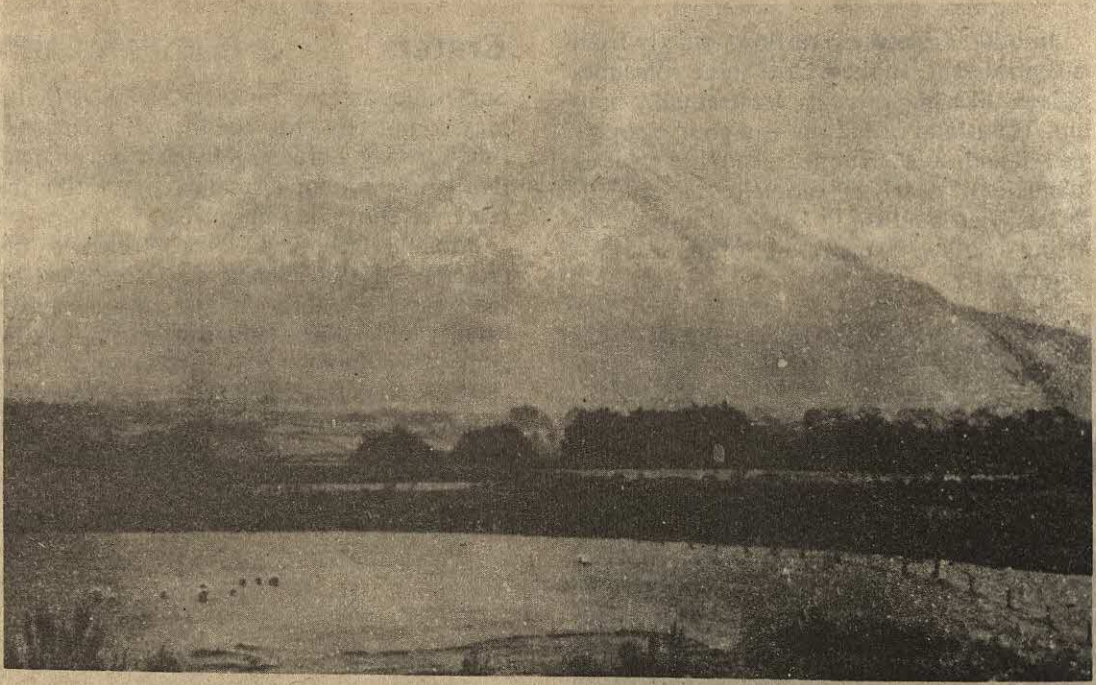
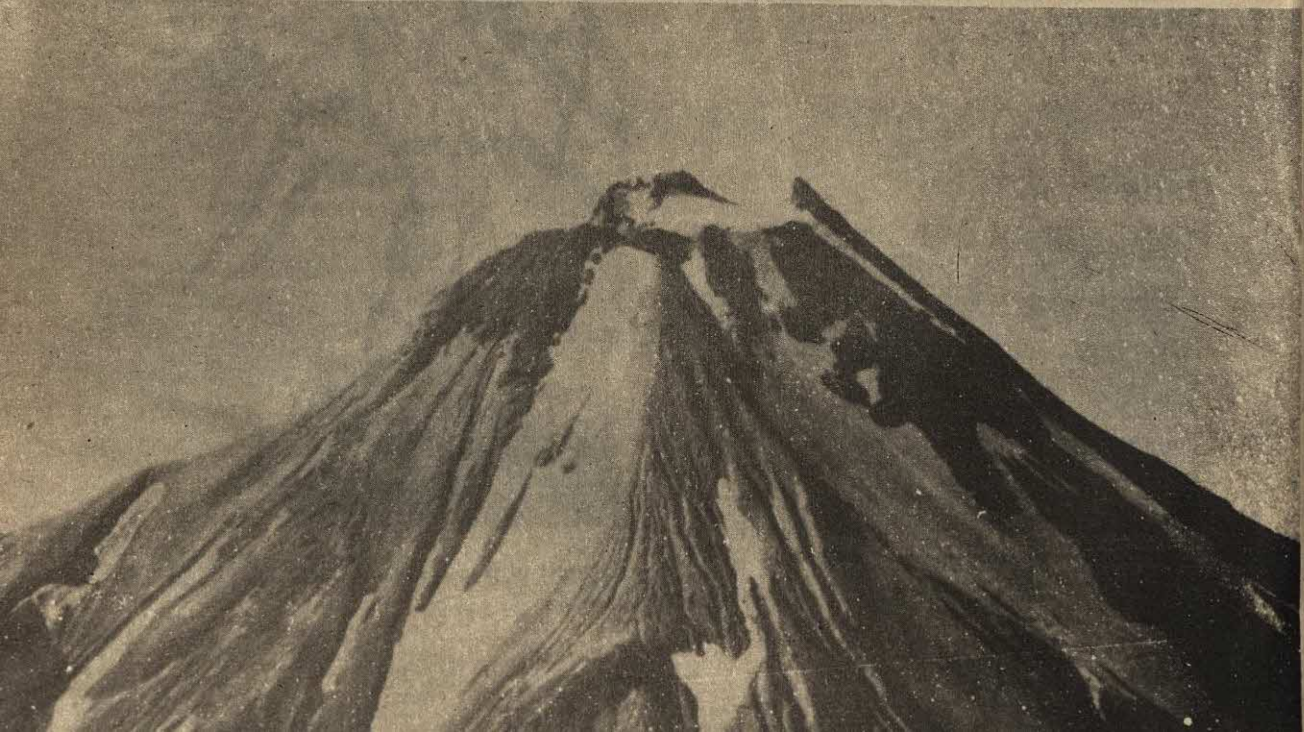
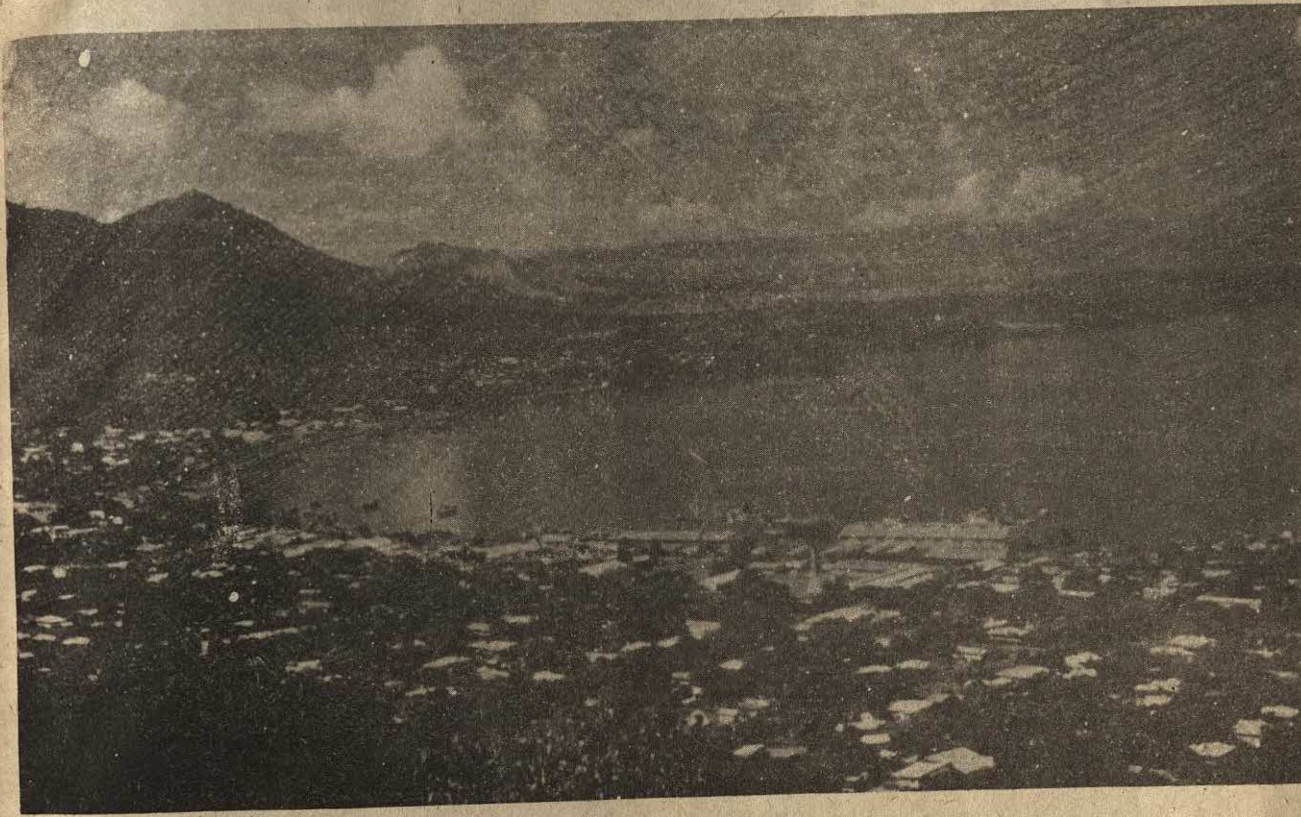


Figure 1.7: Mount Egmont, New Zealand, a cone formed by successive periods of violent eruptions and quiet lava flows. (Photo courtesy New Zealand Information Service)

Figure 1.8: A close-up of the summit of Mount Egmont, New Zealand. (Photo courtesy New Zealand Information Service)





Figures 1.9 (above) and 1.10 (below): Rabaul Harbour in New Britain. A small active volcano can be seen in each photograph. The larger mountains around the harbour are extinct volcanoes. The harbour itself is the crater of an old volcano, which has been partially filled by the sea. (Photo courtesy former Department of External Territories)

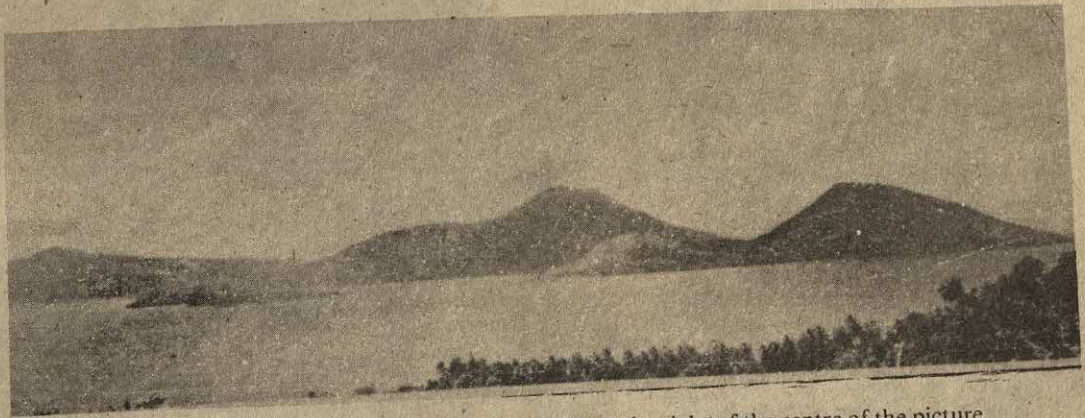


Figure 1.10: Rabaul Harbour. The active volcano is a little to the right of the centre of the picture.

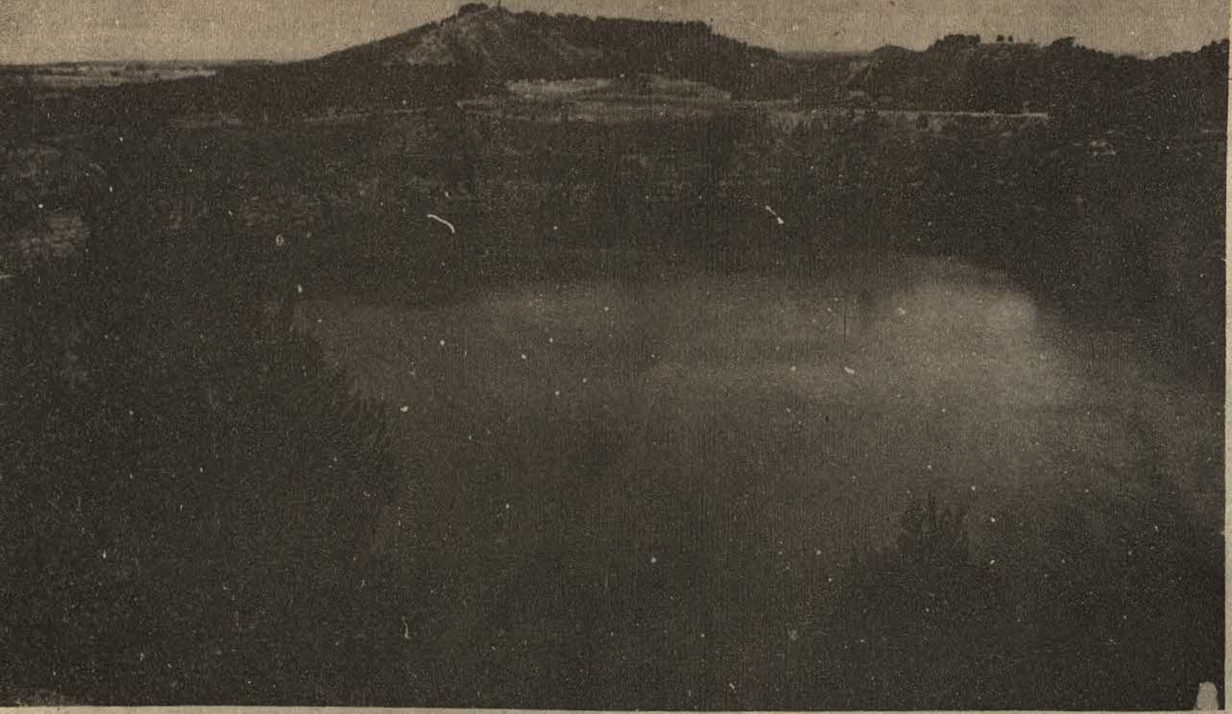


Figure 1.11: Blue Lake, Mount Gambier, South Australia. This is a very deep lake formed by the filling of the crater of an extinct volcano with water.

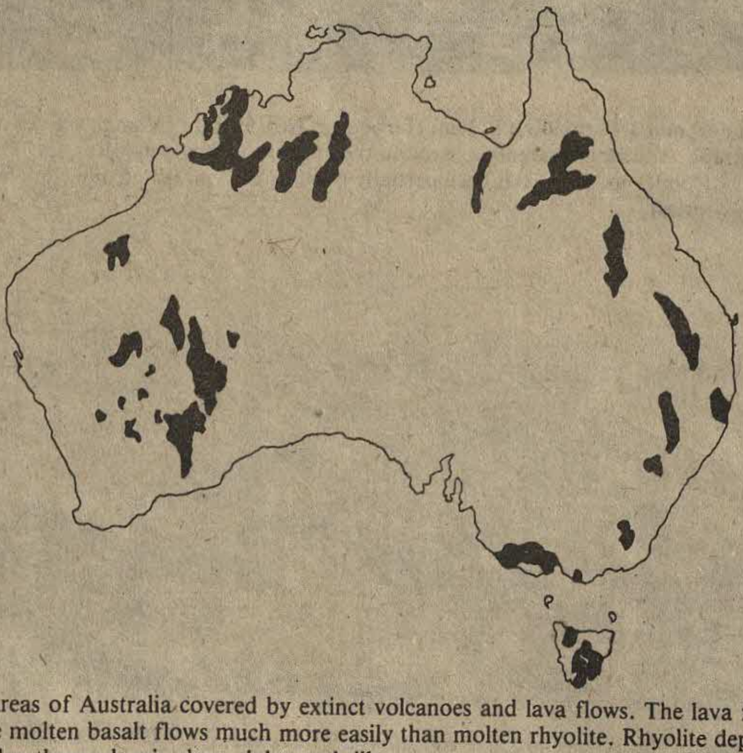


Figure 1.12: Areas of Australia covered by extinct volcanoes and lava flows. The lava flows are mostly basalt, because molten basalt flows much more easily than molten rhyolite. Rhyolite deposits do not extend much further than volcanic plugs, dykes and sills.

Eroded plugs

Extinct volcanoes are gradually worn down by erosion. However, the solidified lava in the vent of the volcano (called the plug) is usually more resistant to erosion than is the material in the cone. Thus, when the cone has been worn away, an eroded plug may be left sticking up sharply above the surrounding countryside. There are a number of these plugs in the Warrumbungle Mountains and the Nandewar Range, both in New South Wales. The Glasshouse Mountains in Queensland are other good examples of eroded plugs.

Hot springs

Hot springs are openings through which hot ground water reaches the surface. The water has usually been heated by the presence of a body of magma in the region.

Because minerals dissolve more easily in warmer water, the water in hot springs is often highly mineralized.

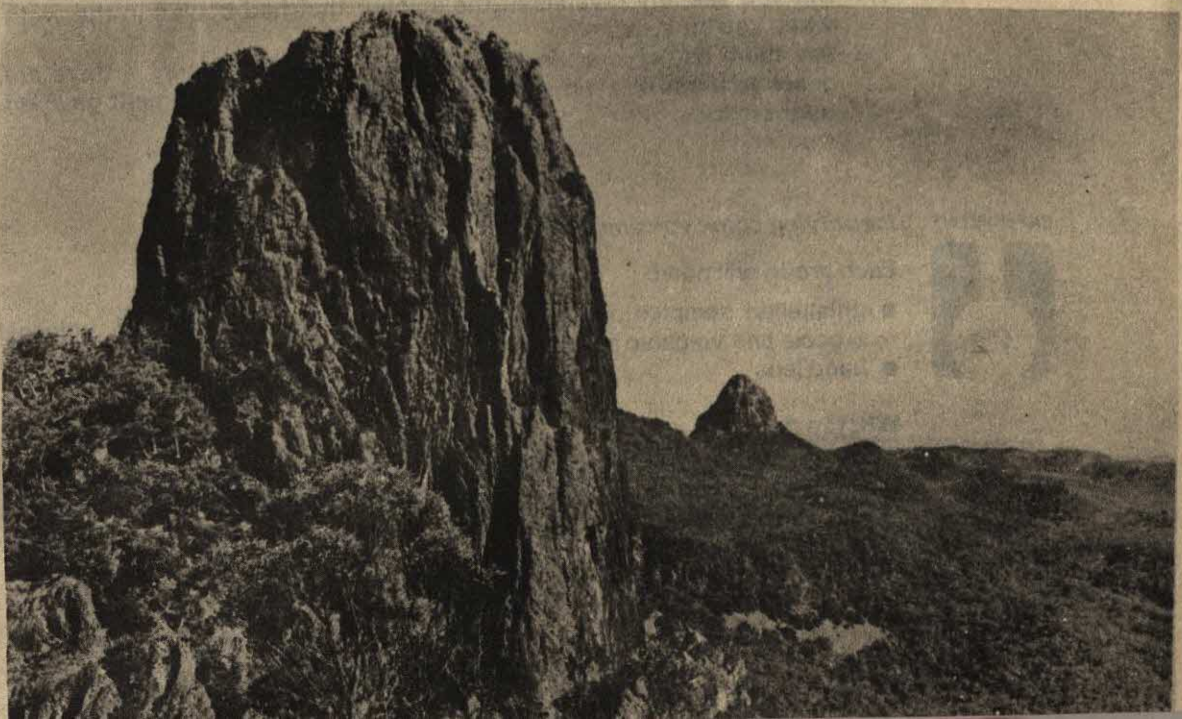
Geysers

Geysers are hot springs that periodically erupt. Many of them occur in New Zealand, Iceland and the United States.

The water in a geyser occupies a natural tube-like space going down into the ground. The pressure at the bottom of the tube is higher than at the top, so the boiling point of the water is higher at the bottom. For this reason the whole column of water can be heated to near boiling point. A very small decrease in pressure, caused by a little of the water boiling, will make a large part of the water turn suddenly to steam. The pressure of the steam forces out a column of steam and boiling water, sometimes to considerable height. Then the whole process is repeated.

Much of the water in hot springs and geysers comes from magma. It is lost from the cooling magma as the magma crystallizes. The presence of water in quantity generally means that most of the magma in that area of the crust has solidified. This of course means that the area is decreasing in volcanic activity.

Figure 1.13: Crater Bluff and Mount Tonduron, volcanic plugs in the Warrumbungle Mountains, New South Wales. (Photo courtesy New South Wales Department of Tourism)



EXPERIMENT 1.1

Cooling molten sulphur under two different conditions

Each group will need:

- evaporating basin
- powdered sulphur
- tin lid
- sand
- tripod
- Bunsen burner
- glass rod
- beaker
- filter funnel
- filter stand
- filter paper

What to do

- Place the sulphur in the evaporating basin on the tin lid of sand on a tripod, and heat gently.
- Stir the sulphur as it begins to melt. Just after it has melted, the sulphur is a watery, honey-coloured liquid. Do not make the sulphur hotter or it will become thick and dark.
- Pour some of the watery liquid into a beaker of cold water and observe what happens.
- Pour the remainder of the liquid sulphur into a folded filter paper in a filter funnel.
- When a crust has just formed on the sulphur in the filter paper, open out the paper and let the sulphur that is still molten drain back into the evaporating basin.
- Break the piece of solid sulphur that cooled in the beaker of cold water.

Questions

1.1 Did you see any crystals in the sulphur that had cooled in the water when you broke it?

1.2 Are there any crystals in the sulphur on the filter paper? If there are, describe them. Explain why the two parts of the experiment gave different results.

EXPERIMENT 1.2

Identifying some volcanic rocks

Each group will need:

- unlabelled samples of basalt, rhyolite, obsidian, pumice, tuff, volcanic breccia and volcanic agglomerate
- hand lens

What to do

- Number your rock samples if they have not been numbered already.
- Examine each rock in turn. Note particularly grain size, colour, flow lines and gas bubbles if present, and kinds of particles present.

Name each rock and enter your results in a table.

Rock no.	Colour	Grain size	Special features	Name of rock

Volcanoes and volcanic rocks

- Volcanoes are openings in the earth's crust that erupt from time to time.
- Volcanic eruptions may be quiet lava flows or violent explosions. Both types of eruption commonly take place from the same volcano.
- Lavas may be basic and very fluid, or acid and very sticky.
- In explosive eruptions gases escape and solid rock fragments are thrown out.
- Lavas form fine-grained rocks such as basalt and rhyolite.
- Quickly chilled lavas form glassy rocks such as obsidian and pumice.
- Volcanic fragments form rocks such as tuffs, breccias and agglomerates.
- Some features of volcanic landscapes are
    - flows
    - cones
    - craters
    - eroded plugs
    - hot springs
    - geysers.

Spelling list

agglomerate
breccia
column
columnar
conchoidal
extinct
feldspar
ferromagnesian
funnel
geyser
glassy
Hawaii
lava
magma
obsidian
Rabaul
rhyolite
sulphur
tuff
volcanoes

Things to do

1.3 Draw a map of the world and mark on it with crosses the places where there are active volcanoes. (Look in your school library for the information.) Do volcanoes seem to occur in groups or lines, or scattered around all over the place?

1.4 Scientists in the past had a number of conflicting ideas about the way rocks were formed. Find out from your library what the Neptunists believed. Why was their theory finally discarded?

More questions

1.5 Explain the difference between lava and magma.
1.6 Why are rhyolites lighter in colour than basalts?
1.7 Why do volcanic shields have flatter slopes than volcanic cones?
1.8 What is a mixed eruption?
1.9 Explain how craters form.
1.10 How are volcanic glasses formed?
1.11 Why does pumice float on water?
1.12 Tuff, volcanic breccia and volcanic agglomerate are all rocks formed from volcanic fragments thrown out from a vent. Which of these rocks is found furthest from the vent and which closest to the vent? Give reasons for your answers.
1.13 Would you classify a tuff as a sedimentary or an igneous rock? Explain your answer.
1.14 Give a modern theory to explain the melting of rocks deep in the earth's crust.
1.15 Fragmental rocks containing fragments of rhyolite are more common than those containing fragments of basalt. Explain this fact

Test yourself (chapter 1)

1. Complete the following table, writing the answers in your workbook.

a very fine-grained volcanic fragmental rock	(a)
a dark, fine-grained volcanic rock	(b)
a glass containing many tiny gas holes	(c)
a black volcanic glass	(d)
a light-coloured, fine-grained volcanic rock	(e)
a fragmental rock consisting of larger angular fragments cemented in fine volcanic ash	(f)
a fragmental rock consisting of large blocks of rock cemented in finer volcanic fragments	(g)

2. What characteristics help you distinguish between breccia and conglomerate?
3. Which rock is the more fluid in the molten state — rhyolite or basalt?

Choose the best answer to each of questions 4 and 5 and write its letter in your workbook.

4. The island of Hawaii is a mountain with long gentle slopes to the sea. This shape is the result of:
   (a) erosion by water and strong winds
   (b) volcanic eruptions with a lot of ash
   (c) lava flows of basalt
   (d) lava flows of rhyolite.

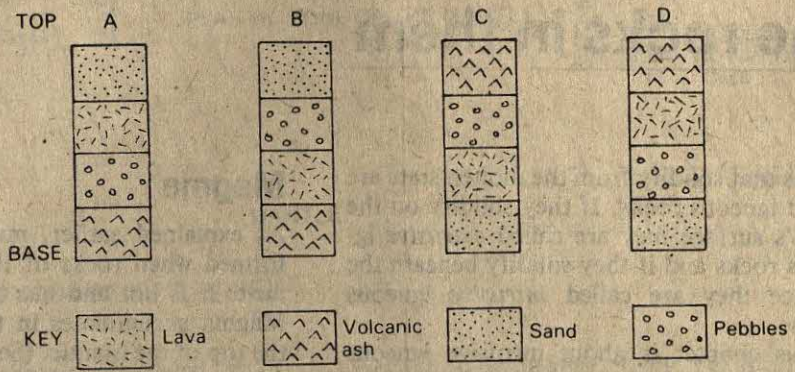


Figure 1.14

5. Figure 1.14 shows four cylinders of rock ("cores") drawn out of the earth's crust during drilling. Which one of the cores best fits the following sequence of events?
   First event. Volcanic ash covered the land.
   Second event. Lava flowed over the land.
   Third event. The land sank below sea level and pebbles were deposited.
   Fourth event. The water deepened and sand was deposited.

2

Igneous intrusions and the rocks in them

Rocks that solidify from the molten state are called igneous rocks. If they solidify on the earth's surface they are called *extrusive* igneous rocks and if they solidify beneath the surface they are called *intrusive* igneous rocks.

This chapter is about intrusive igneous rocks. Chapter 1 discussed extrusive igneous rocks.

Magma

As explained earlier, magma is the liquid formed when rocks of the crust or mantle melt. It is hot and has the ability to flow. Magma accumulates in the plastic zone at the top of the mantle. (See figure 2.2.) It is a mixture of silica and other oxides and often contains some crystals in the liquid.

Figure 2.1: Part of the Kosciusko Batholith as seen from Geehi in Victoria. The batholith is a huge mass of coarse-grained igneous rock that was originally deep down in the earth's crust. (Photo courtesy Snowy Mountains Hydro-Electricity Authority)

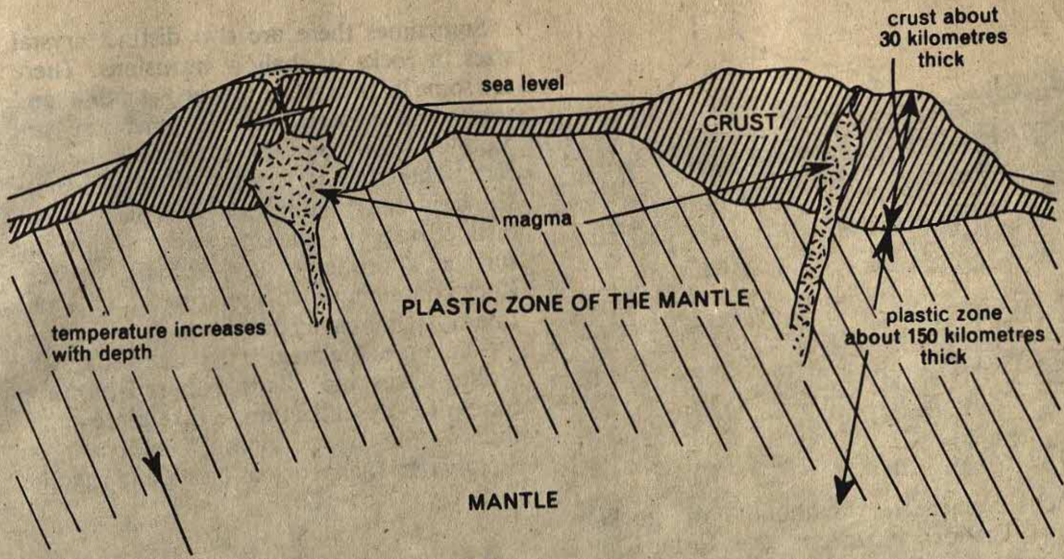


Figure 2.2: The occurrence of magma in the earth.

Magmas also contain dissolved gases. These gases include steam, carbon dioxide, sulphur vapour, chlorine, nitrogen, hydrogen sulphide and sulphur dioxide. When the magma cools some of these gases are given off. As they accumulate under the crust they exert pressure. This pressure, together with the pressure of the rock above, may cause the magma to move. Movement occurs especially where there is a weakness in the earth's crust; the magma may reach the surface through the weakest part of the existing rocks.

Magmas vary in composition. The acid magmas are those with a lot of silica. They are viscous and flow very slowly even on steep slopes. The basic magmas are those with less silica. They flow easily. The minerals in acid magmas crystallize at lower temperatures than the minerals in basic magmas.

Intrusions

There are two kinds of intrusions — shallow intrusions and deep intrusions. The deep intrusions are sometimes called plutons.

Deep intrusions. Magma deep below the earth's surface has a lot of rock above it. This acts as an insulator, so that heat escapes from the magma very slowly. For this reason the magma takes a long time to solidify — in some cases more than a million years. This gives crystals time to grow: coarse-grained rocks are the result.

Examples of rocks formed in deep intrusions are granite and gabbro. Granite is a light-coloured rock rich in quartz (an acid rock), whereas gabbro is a dark rock rich in ferromagnesian minerals (a basic rock).

Some deep intrusions are eventually exposed to the atmosphere. This can happen only after millions of years because there is so much surface rock to be eroded away. If the exposed area of a pluton exceeds 100 square kilometres it is called a batholith. One of the largest known is the Idaho batholith in the United States; it has an area of 40 000 square kilometres. Batholiths in New South Wales are smaller; they are the New England batholith, the Bathurst batholith and the Kosciusko batholith. (See figure 2.1.)

Small offshoots of batholiths are called stocks. They have an exposed area of less than 100 square kilometres. Figure 2.3 shows a batholith and a stock.

Shallow intrusions. Shallow intrusions are not only closer to the earth's surface but also

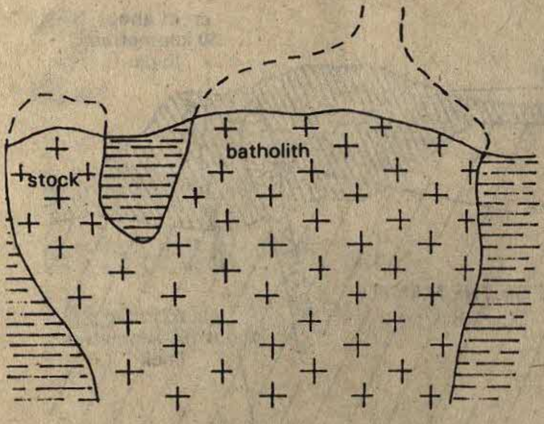


Figure 2.3: Plutons.

much thinner than batholiths or stocks. Some shallow intrusions are formed by magma forcing its way into joints or between layers of rock, as shown in figure 2.4.

Sills are formed when magma is forced between layers of rock whereas dykes are formed when magma is pushed into cracks across the layers. Figure 2.5 shows sills and dykes spreading out from the vent pipes of a volcano.

Because they are much thinner and closer to the surface, shallow intrusions cool much more quickly than deep intrusions. This results in fine- to medium-grained rocks. Dolerite is such a rock.

Sometimes there are two distinct crystal sizes in rocks in shallow intrusions. There are some large crystals, formed at depth, and some fine crystals, formed when the still mobile magma moved up towards the surface. There are no crystals of intermediate size because crystallization took place in two distinct stages — one slowly, deep below the surface, and one quickly, near the surface. Rock containing such a mixture of large and fine crystals is called porphyry.

Sometimes the magma is pushed so quickly into dykes and sills that there is no time for earlier crystallization to take place at all. Indeed, the crystallization may occur so rapidly that rocks such as basalt and rhyolite

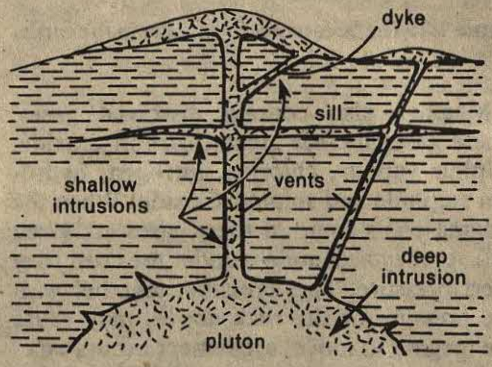
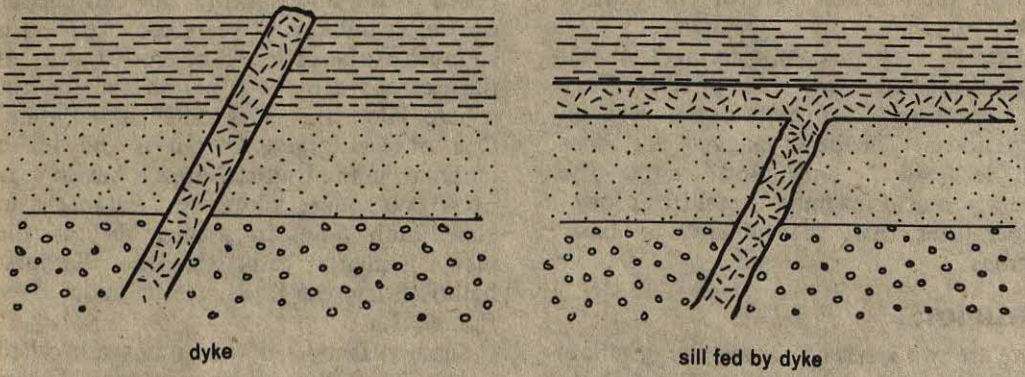


Figure 2.5: Intrusions.



Dykes cut across the rocks they intrude.

Sills intrude between layers of rock.

Figure 2.4: Shallow intrusions.

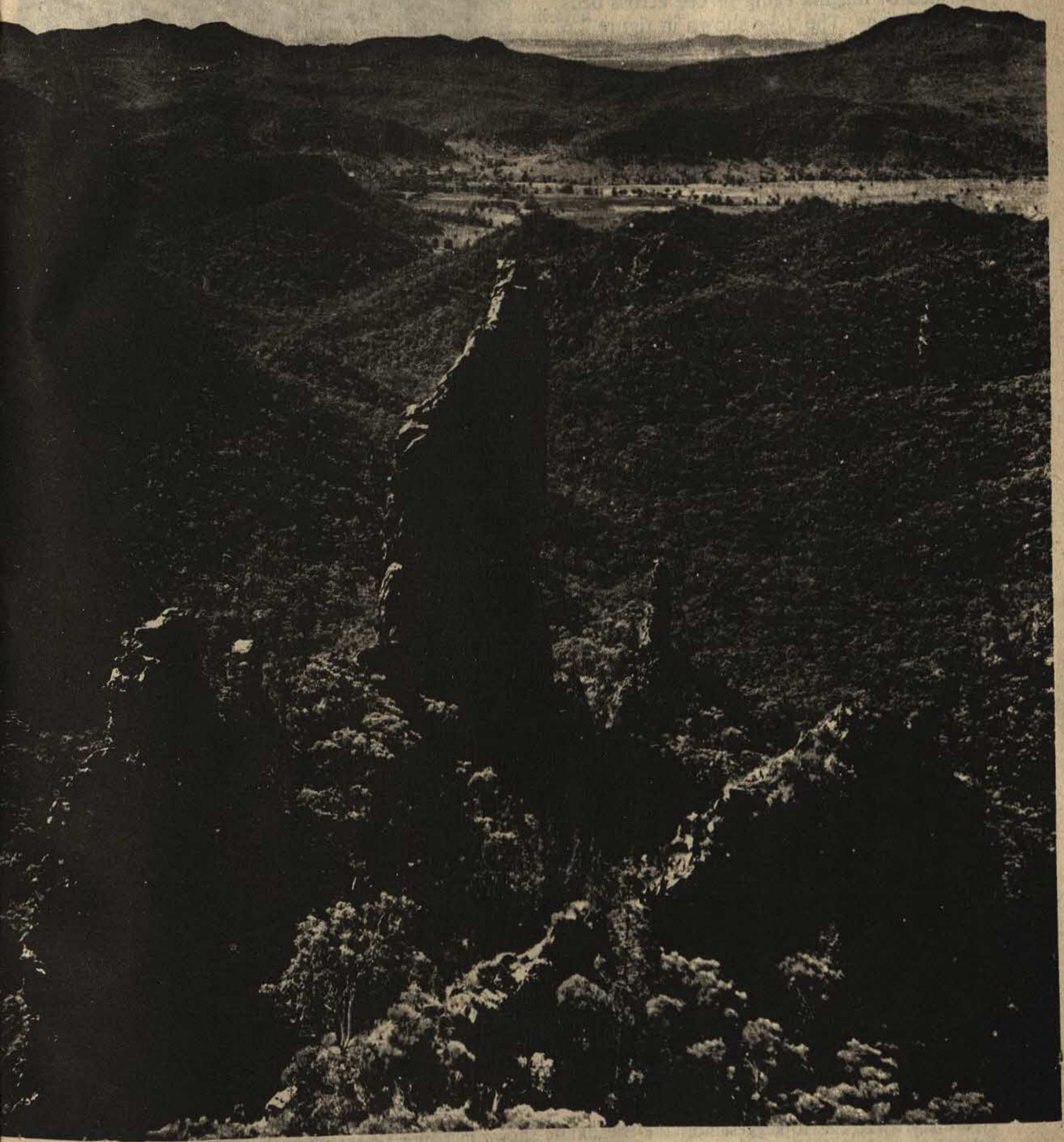


Figure 2.6: The Breadknife, a dyke in the Warrumbungle Mountains in New South Wales. (Photo courtesy New South Wales Department of Tourism)

are formed. Figure 2.7 shows a basalt dyke formed by magma being forced across beds of sandstone. The dyke shown in figure 2.6 is composed of trachyte, a light-coloured rock with a little less quartz than rhyolite. It has resisted erosion more than the adjacent rocks and therefore stands out above the surrounding countryside.

Kinds of igneous rocks

There are many different kinds of igneous rocks. For example, there are the two fine-grained rocks rhyolite and basalt. Rhyolite is light-coloured whereas basalt is dark. As you can imagine, there are grades of rocks between these two extremes. As mentioned earlier, trachyte is a rock containing a little less quartz than rhyolite. Andesite is the name given to a rock that contains a slightly smaller proportion of ferromagnesian minerals than basalt.

As this is an introduction to the subject, we shall describe only a few of the more common igneous rocks. These are listed in table 2.1 and described more fully in tables 2.2 and 2.3. See appendix 1 (page 278) for a table giving a fuller list of igneous rocks, for reference only.

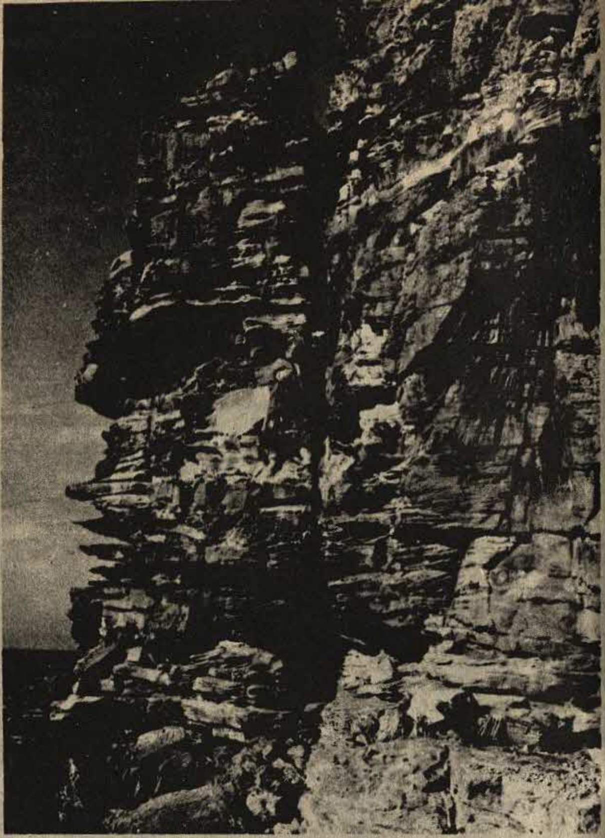


Figure 2.7: A basalt dyke cutting through the Hawkesbury Sandstone north of Bondi beach, Sydney. The basalt has mostly weathered to clay, which has been partly removed by erosion.

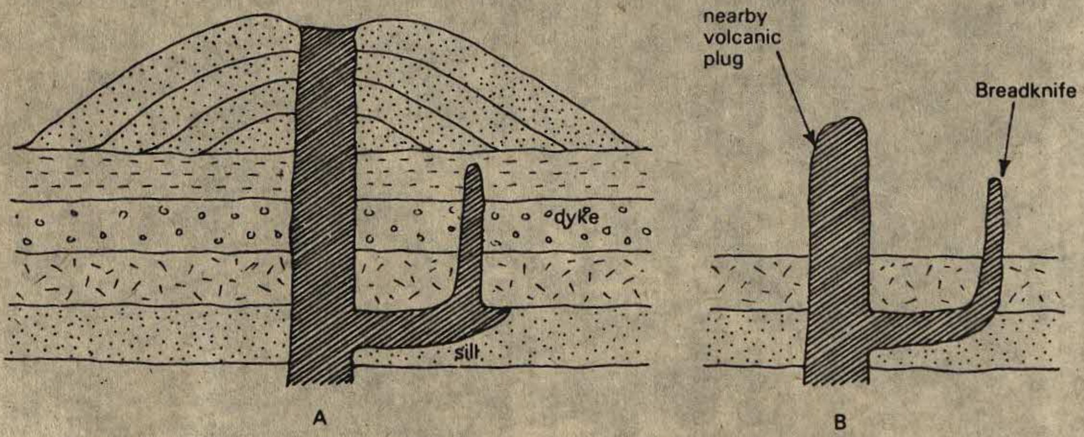


Figure 2.8: Diagrams to suggest how the Breadknife shown in figure 2.6 may have been formed. The volcanic core and the nearby dyke have resisted weathering and erosion much more than have the surrounding rocks.

Table 2.1: Some igneous rocks

Average grain size (decreasing)	Lignt-coloured rocks	Dark-coloured rocks
	granite	gabbro
	porphyry	dolerite
	rhyolite	basalt

Table 2.2: Acid igneous rocks

Rock	Type	Where found	Description
Granite	plutonic	in large deep intrusions such as batholiths and stocks	A light-coloured pink or grey rock. It contains large grains of quartz, feldspar, mica and ferromagnesian minerals interlocked with each other.
Quartz orthoclase porphyry	plutonic	in small intrusions such as dykes and sills	A light-coloured rock containing large grains of orthoclase feldspar and quartz set in a mass of fine-grained rock. The large grains form first. As the magma cools the finer grains solidify rapidly around the larger ones.
Rhyolite	volcanic	in extrusions (lava flows)	A light-coloured, very fine-grained rock containing the same minerals as granite. The mineral grains cannot be seen with the naked eye. The rock sometimes shows flow bands.

Table 2.3: Basic igneous rocks

Rock	Type	Where found	Description
Gabbro	plutonic	in large deep intrusions such as batholiths and stocks	A dark-coloured rock. It contains large grains of feldspar, ferromagnesian minerals and sometimes magnetite, all interlocked with each other.
Dolerite	plutonic	in small intrusions such as dykes and sills	A dark-coloured rock, similar to gabbro but with finer grains.
Basalt	volcanic	in extrusions (lava flows)	A dark-coloured, very fine-grained rock containing the same minerals as gabbro. Most of the mineral grains cannot be seen with the naked eye.

EXPERIMENT

2.1

Identifying some igneous rocks

Each group will need:

- unlabelled samples of the following rocks – granite, some porphyries, rhyolite, pumice, gabbro, dolerite and basalt
- hand lens

What to do

- Number your rock samples if this has not already been done.
- Examine each sample carefully. Note particularly the colour, grain size and whether or not the rock is a porphyry.
- Tabulate your results as follows, by putting the number of each sample examined in an appropriate box.

Colour of rock	Coarse-grained	Medium- to fine-grained	Two distinct grain sizes	Very fine-grained
light-coloured				
dark-coloured				

Questions

2.1 Which of the rocks examined are obviously intrusive?
2.2 Which of them are doubtful, that is, they may be intrusive or extrusive?
2.3 How does pumice differ from rhyolite?
2.4 Which rocks contain free quartz?
2.5 Which rocks contain no free quartz?
2.6 Which contains the larger proportion of ferromagnesian minerals – gabbro or granite?
2.7 In what respect are gabbro, dolerite and basalt similar?
2.8 In what respect are gabbro, dolerite and basalt dissimilar?

EXPERIMENT

2.2

Drawing a section through a granite batholith from the data supplied in figure 2.9

Each person will need:

- ruler marked in mm
- protractor
- pencil and rubber

What to do

- Draw a line in your workbook a little longer than AG in figure 2.9. Mark off on it the intervals between the points A to G inclusively. Call these points A′, B′, C′, etc.
- Using a scale of 1 cm to 100 m, draw verticals to represent the heights of A, B, C, etc., above sea level. Label these points A, B, C, etc.
- Join A to B to C, etc. This will give you an outline of the surface of the land.
- At A draw a straight line dipping 20° to the left. At G draw a straight line

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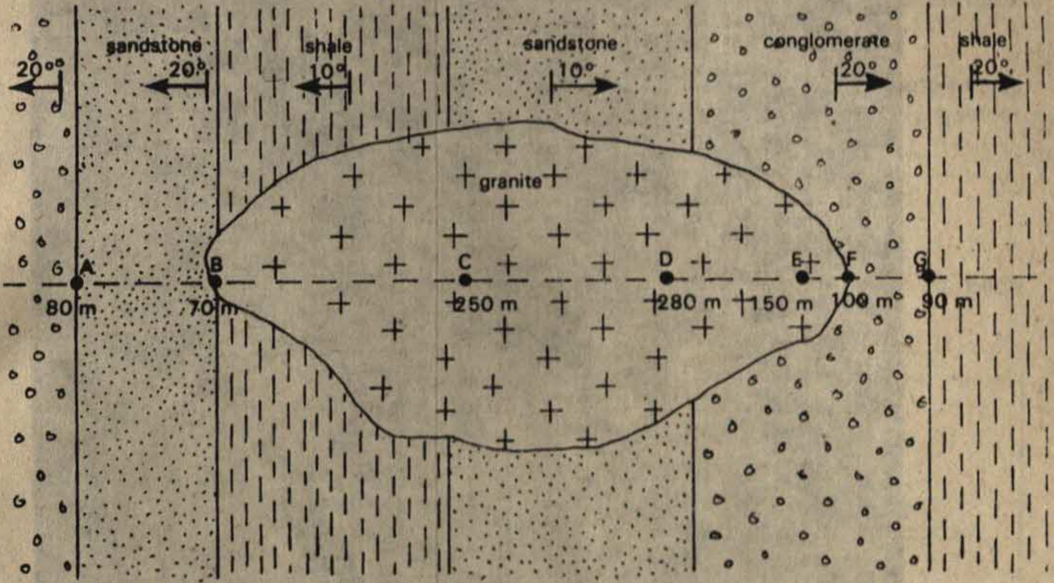


Figure 2.9: A map showing a granite batholith exposed by the erosion of sedimentary rocks that were originally on top of it. The numbers of metres are the heights above sea level at the points indicated. The angles marked above the arrows give the slope, or dip, of the surrounding sedimentary beds.

dipping 20° to the right. These lines give you the underground boundaries of the sedimentary rock layers on either side of the batholith.

- Outline the rock boundaries below ground level. Use your own judgment in outlining the batholith; it is likely to be bigger underneath than on top.
- Compare your finished drawing with figure 2.12 in appendix 2.

EXPERIMENT

2.3

A geological excursion into an igneous area

The best sites for this excursion are quarries or places where there are exposed igneous formations such as volcanic plugs. If you are planning to enter private property, seek the owner's permission beforehand.

Each person will need:

- a pair of old shoes
- rucksack
- notebook and pencil
- hand lens
- penknife
- file
- geological hammer
- newspaper for wrapping rock specimens
- first-aid kit for the group
- camera
- sledge-hammer if going into a quarry

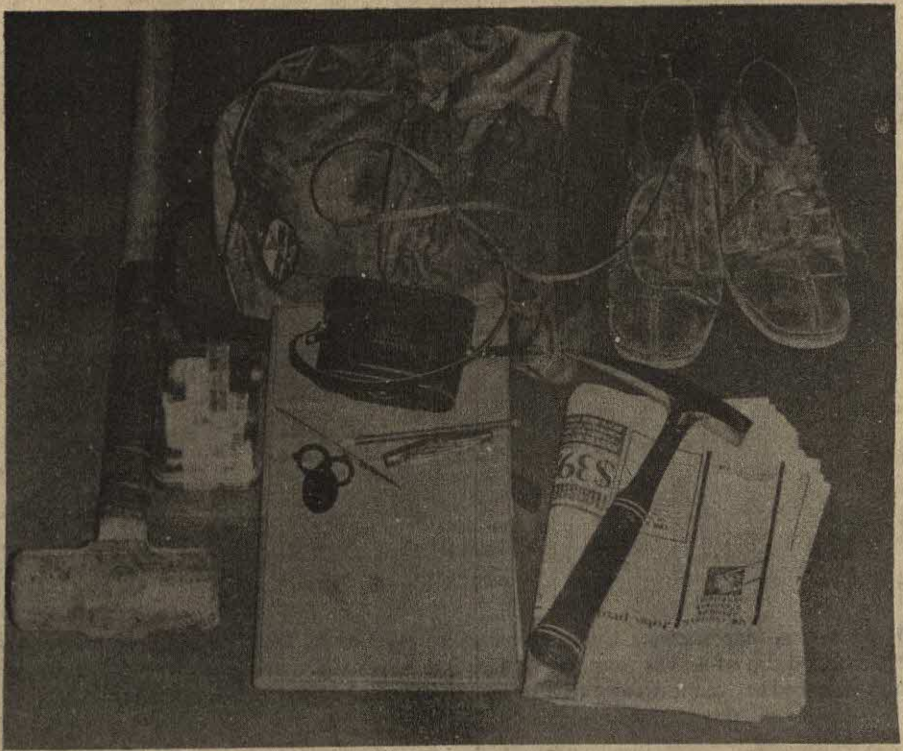


Figure 2.10: Equipment needed on a geological excursion.

What to do

- Try to obtain a geological map of the area. (Contact the mines department in your state.) From it find out the kinds of formations you are likely to encounter on the site you have selected for the excursion.
- Have a group discussion before you arrive at the site. Draw up a list of rules to be followed. Three rules you should include are:
  - (a) Avoid the edges of cliff faces, especially in quarries, where the rock may crumble beneath you.
  - (b) Stand clear of anyone using a hammer. Flying rock fragments could enter your eyes.
  - (c) Clean up any litter before leaving the site, even if it was left by previous visitors.
- At the site, identify the types of outcrop in which the igneous rocks occur.
- Collect rock samples. Wrap each sample with a numbered piece of paper and then with newspaper.
- For each sample write in your notebook
  - (a) the name of the rock
  - (b) where at the site it was found
  - (c) any special features noticed.

- If in a lava flow area, search for rocks showing flow structure or containing gas bubbles. (Refer to figure 1.2.)
- Locate any jointing in the rocks. (Refer to figure 1:3.)
- Examine any sedimentary rocks close to the outcrop. Make a note of any features that indicate that these rocks have been changed by heat or pressure. Your teacher will help you recognize these features.
- After the excursion write a short report. Include
  - (a) a paragraph about the way the outcrop was probably formed
  - (b) a map of the site
  - (c) photos with explanatory notes
  - (d) a list of rock specimens collected with a description of each specimen.

Igneous intrusions and the rocks in them

- Igneous rocks are rocks formed when molten rock solidifies.
- Igneous rocks formed on the surface, from lava, are extrusive rocks.
- Igneous rocks formed beneath the surface, from magma, are intrusive rocks.
- Intrusions may be shallow or deep.
- Some shallow intrusions are dykes and sills.
- Deep intrusions are either stocks or batholiths.

Spelling list

batholith
crystallize
dolerite
dyke
extrusive
feldspar
ferromagnesian
gabbro
granite
igneous
intrusive
orthoclase
porphyry
rhyolite
sill
trachyte

Things to do

2.9 Visit the geological section of a museum. Examine rock specimens and other displays.

2.10 If you are going to be travelling through the countryside, familiarize yourself beforehand with any interesting geological features you are likely to see. Look out for these on your journeys.

2.11 Make a collection of interesting rock specimens. (Remember to label them all.) Try to obtain rocks of types that are not found in your local area.

More questions

2.12 Draw a single diagram to include examples of all of the following formations — batholith, sill, dyke, extinct volcano, old lava flow and volcanic plug.

2.13 Describe, with the aid of diagrams, some of the structures that can result when igneous rocks in dykes weather at rates different from the surrounding rocks.

Test yourself (chapter 2)

1. Name a light-coloured, fine-grained igneous rock.
2. Name a dark-coloured, coarse-grained igneous rock.

In questions 3 to 10, choose the best answer and write its letter in your workbook. Questions 3 to 9 refer to figure 2.11, which represents a section through an extinct volcano.

3. Igneous rocks with the coarsest grain are likely to be found at
   (a) T (b) R (c) U (d) S.
4. A dyke is the formation marked
   (a) U (b) S (c) Q (d) R.
5. A sill is the formation marked
   (a) U (b) S (c) Q (d) R.
6. The oldest rock is
   (a) M (b) T (c) U (d) Q.
7. Which of the following rocks would be most likely to be found at T?
   (a) basalt
   (b) granite
   (c) dolerite
   (d) pumice.
8. The rock in layer P can be generally classed as
   (a) volcanic
   (b) plutonic
   (c) intrusive.
9. A batholith is the formation marked
   (a) U (b) T (c) Q (d) R.

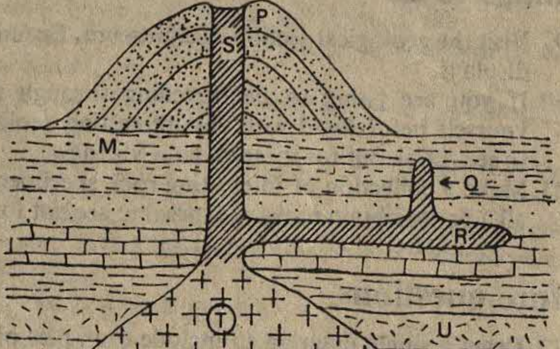


Figure 2.11

10. Granite consists of a collection of large grains of several different minerals. Geologists believe that granite is formed deep in the earth's crust. They have come to this conclusion because:
    (a) Igneous rocks with large crystals are always found underground.
    (b) Experiments show that when minerals are melted and then cooled slowly large crystals are produced.
    (c) In the laboratory igneous rocks with large crystals melt at lower temperatures than those with small crystals.
    (d) The minerals that make up granite always form large grains.

3

Using simple machines

Many of the things we use every day are simple machines. They are designed to make life easier.

Have you ever tried to remove a bottle-top without an opener? It is doubtful whether you have the strength to pull off a bottle-top with your bare fingers, but using an opener makes it easy. Beating an egg is also easy, if you use a mechanical mixer. No great force is needed but quickness of movement certainly is. The egg-beater is a different kind of machine from a bottle-opener. The bottle-opener magnifies a force whereas the egg-beater magnifies movement.

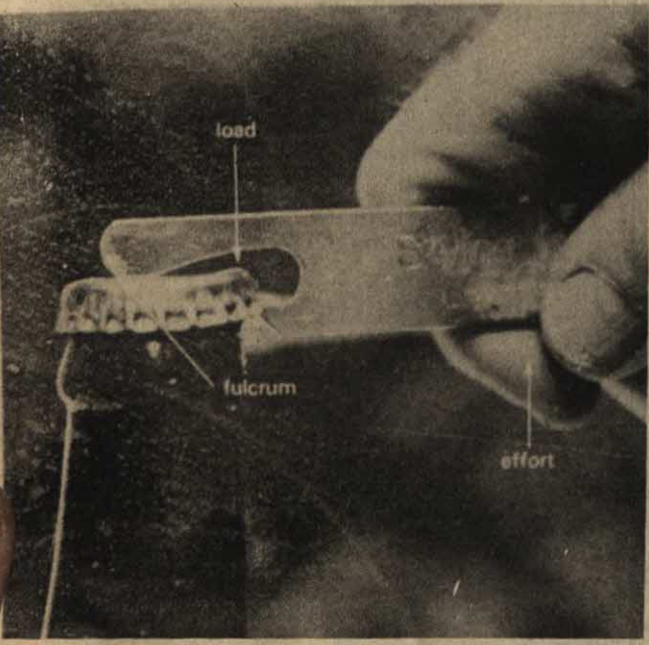


Figure 3.1: The bottle opener is a simple machine. It is a lever.

Even when you walk up steps you are using a simple machine — the slope. It is easier to walk up a slope than to climb vertically on a ladder.

Levers

Look at figure 3.2. This is an example of a simple machine called the lever. It is easy to make a model of this lever using a dowel with a hole in it, pivoting on a nail. (See figure 3.3.)

The load in figure 3.3 is a house brick weighing 4 kilograms. In this experiment it is just moved with a small bag of sand weighing only ¼ kilogram. The load is therefore 16 times the effort. In other words, the machine has magnified the effort 16 times. We say the mechanical advantage is 16.

$$\text{Mechanical advantage (M.A.)} = \frac{\text{Load}}{\text{Effort}} = \frac{4}{1/4} = 16$$

If we refer to figure 3.3 again, we see that the effort is exerted 80 centimetres from the fulcrum whereas the distance from the load to the fulcrum is only 5 centimetres. Thus the *effort arm* is 16 times the *load arm*. This is a common fact about levers.

$$\text{load} \times \text{load arm} = \text{effort} \times \text{effort arm}$$
$$4 \times 5 = 1/4 \times 80$$

If you refer again to figure 3.1 you will see that it shows a different kind of lever from the crowbar shown in figure 3.2. In the

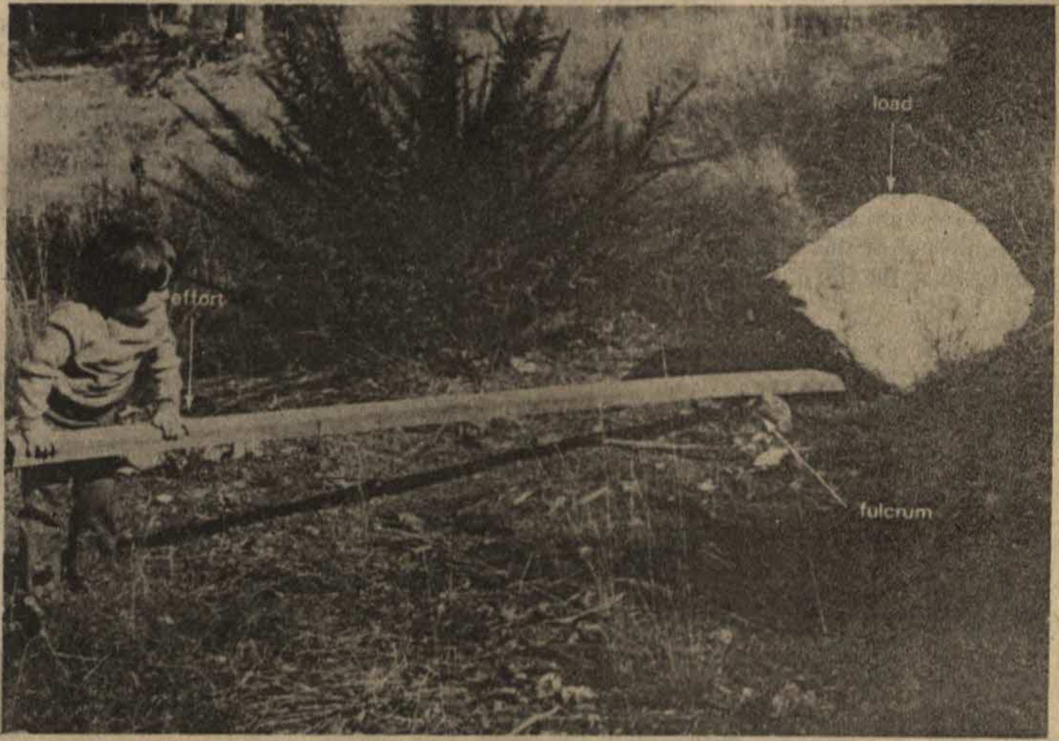


Figure 3.2: Using a simple machine to magnify a force. Here the child is raising a rock that would be impossible to lift with the bare hands. The closer the fulcrum is to the load, the smaller the effort required to move it.

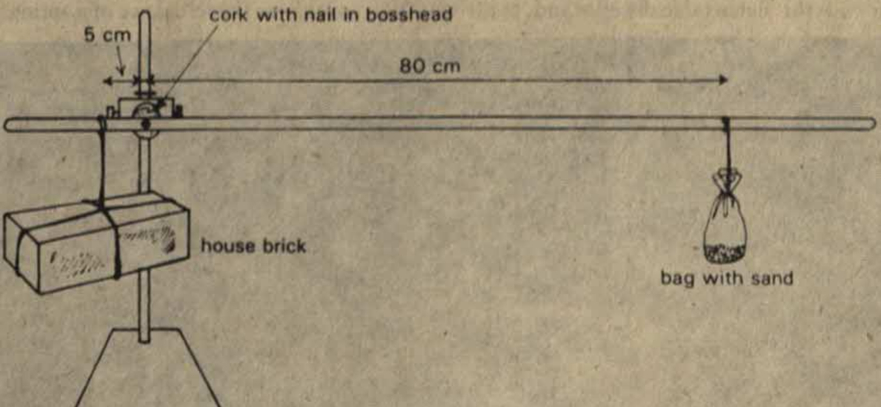


Figure 3.3: Lifting a brick with a force-magnifying lever. The brick weighs 4 kilograms and it is balanced by a bag of sand that weighs only ¼ kilogram.

bottle-opener, the fulcrum is not between the load and the effort but at the end of the lever. This second kind of lever is also a force magnifier and is investigated in more detail in experiment 3.1.

The third kind of lever is a movement magnifier. The simple kitchen tongs shown in figure 3.4 are an example. To pick pieces of ice up out of the bowl you need a large movement at the end of the tongs. The effort required to move the tongs with your fingers is relatively large (larger than if you were using your bare hands). So you trade an increase in the effort for a large movement at the holding end of the tongs.

Table 3.1 classifies the three orders of levers as force magnifiers or movement magnifiers.

Figure 3.5 summarizes the three orders of levers and gives examples of each order.

Table 3.1: The three orders of levers

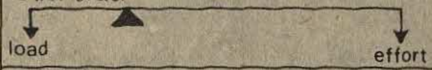
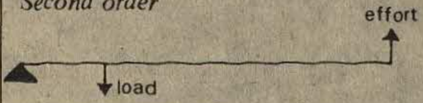
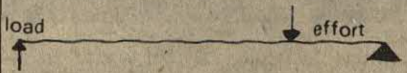
Order (type)	What does the lever magnify?
First order  	Magnifies the effort if the effort arm is greater than the load arm. Magnifies movement if the load arm is greater than the effort arm.
Second order  	Always magnifies the effort.
Third order  	Always magnifies the movement.

Figure 3.4: The tongs used here are an example of the third order of levers. They are actually a double lever with the fulcrum at one end and the load at the other. The effort here is relatively large because it has to move the ends through a large distance and, at the same time, overcome the resistance of a spring.

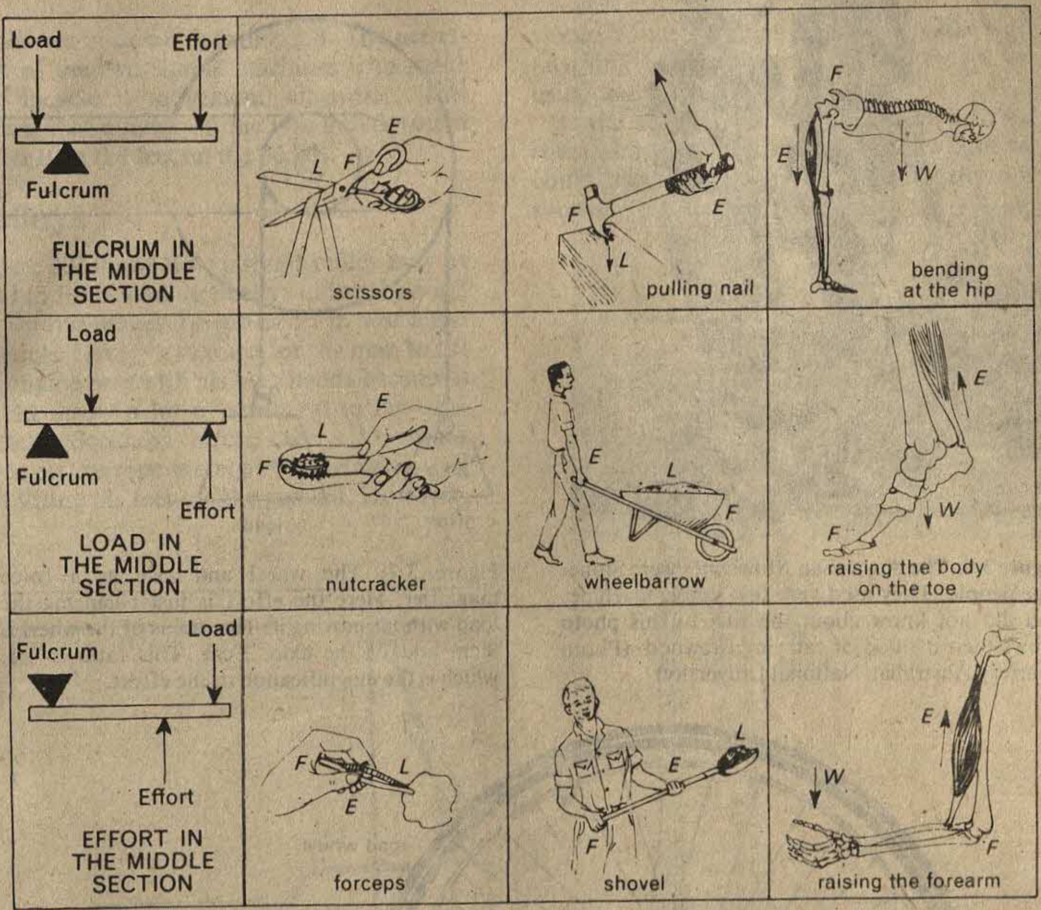


Figure 3.5: Examples of levers.

Wheels

We see wheels used so often that we scarcely notice them. The first wheels were used in the Middle East about 4500 B.C. Before the invention of the wheel, loads were dragged around on sledges or carried on the backs of animals or people. The Australian Aborigines did not know about the wheel — they had no barrows or carts (see figure 3.6).

One of the great human inventions was the bicycle, which enabled people to get about more quickly and easily. A bicycle is faster than walking and much less tiring.

The bicycle makes use of a simple machine called the wheel and axle. This machine is illustrated in figure 3.7, which shows a load of 6 kilograms balanced by an effort of 2 kilograms. (In other words, the wheel and axle is an effort magnifier.) An effort greater than 2 kilograms would be needed to make the wheel rotate because there would be some friction opposing its movement.

The wheel and axle can also be used as a movement magnifier if the effort is applied to the axle and the load to the rim of the wheel.

The way in which the bicycle uses both a force magnifier and a movement magnifier is

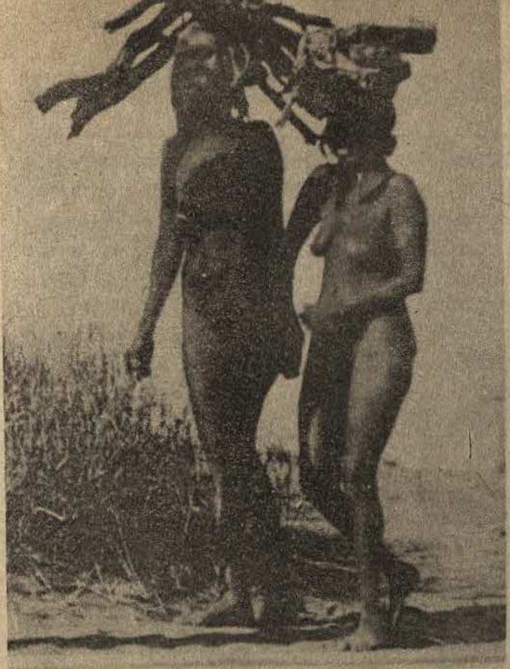


Figure 3.6: The Australian Aborigines were Stone-Age people. They used very few simple machines and did not know about the wheel. This photo shows their method of carrying firewood. (Photo courtesy Australian National University)

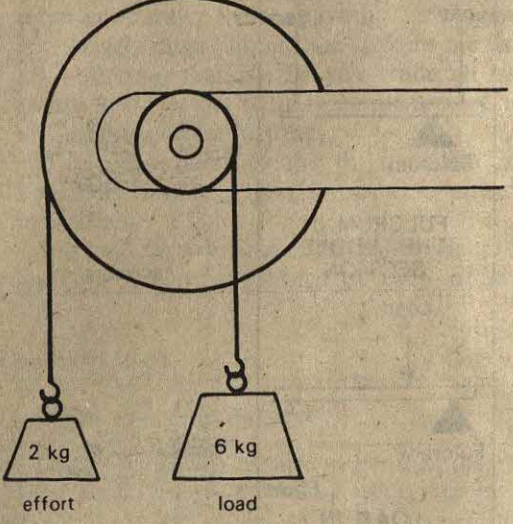


Figure 3.7: The wheel and axle as a force magnifier. Here the effort is just balancing the load without moving it. The radius of the wheel is 9 cm and of the axle, 3 cm. This ratio is 3:1, which is the magnification of the effort.

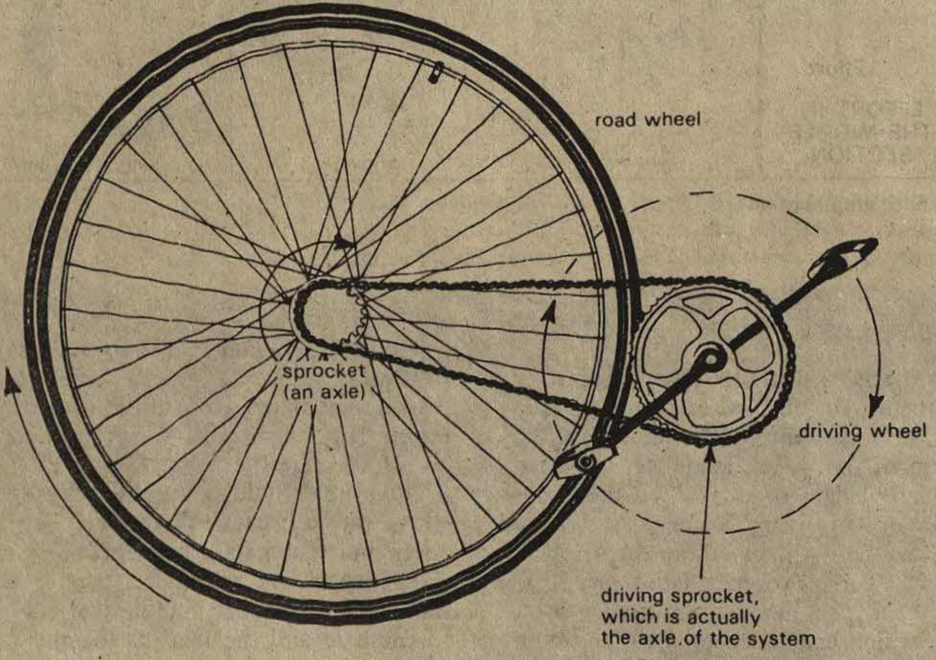


Figure 3.8: The bicycle is a double wheel and axle. The pedals and the large sprocket make up one wheel and axle, which is a force magnifier. The road wheel with its small sprocket is another — quite a large movement magnifier.

explained in detail in figure 3.8. The net effect of the two simple machines is to make the bicycle a movement magnifier. This means that a mark on the tyre moves round faster than the feet on the pedals.

Pulleys

Figure 3.9 shows how a single pulley may be used to lift a load vertically. In the situation shown this makes the job easier in two ways. It would be very awkward for the man to lift the engine part with his bare hands because it would throw a lot of stress on to his back muscles. Secondly, he can exert a downward force on the rope merely by hanging on to it and lifting his feet off the ground. However, would you agree that the man couldn't lift anything heavier than his own weight by using this machine?

If the man in figure 3.9 did need to lift something greater than his own weight he could use a block and tackle like the one shown in figure 3.10.

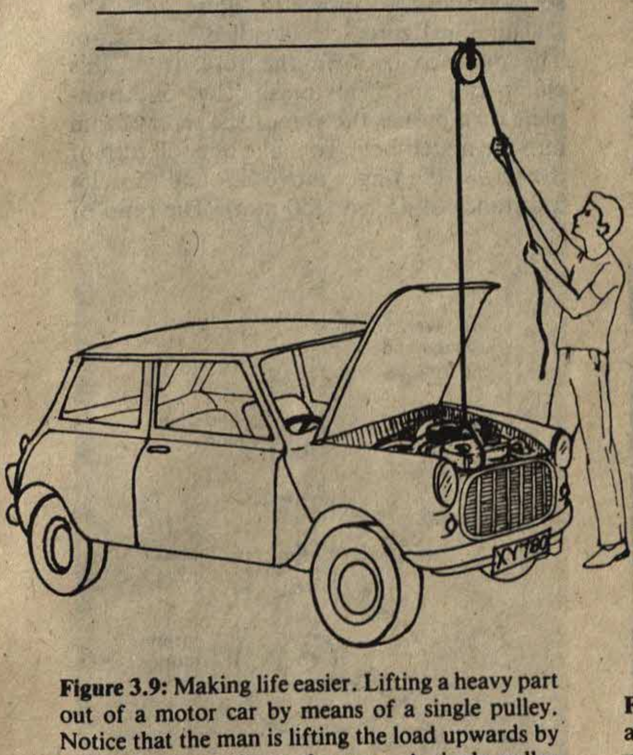


Figure 3.9: Making life easier. Lifting a heavy part out of a motor car by means of a single pulley. Notice that the man is lifting the load upwards by pulling downwards on the rope. A single pulley magnifies neither force nor movement — it only changes the direction of the effort exerted by the man. It would be very awkward for the man to lift this part with his bare hands while bending over the engine.

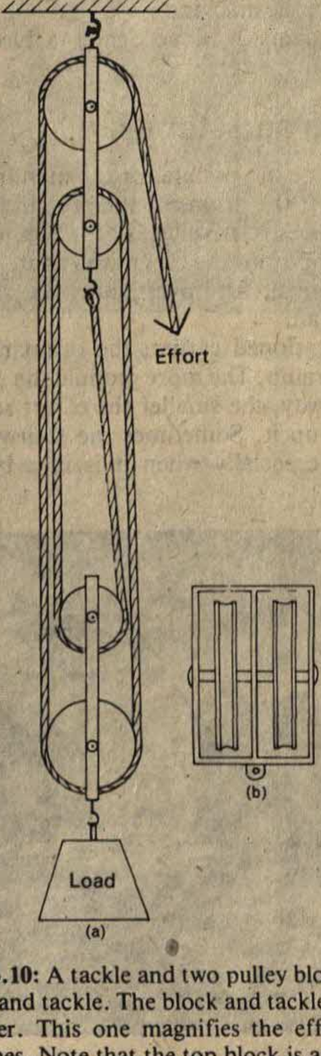


Figure 3.10: A tackle and two pulley blocks called a block and tackle. The block and tackle is a force magnifier. This one magnifies the effort about four times. Note that the top block is attached to a beam and the bottom block moves up with the load. In this diagram the pulleys are shown on separate axes for clarity. In practice they are mounted side by side, as in (b).

A block and tackle is a force magnifier. In this particular one the load is supported on four ropes. This means the load moves up by only one-quarter of the distance the effort moves down. You might think that this block and tackle would have a mechanical advantage of four. Actually, the magnification is a little less than four because the effort has to lift the bottom pulley block as well as the load and also has to work against friction in the machine.

Experiment 3.4 investigates a block and tackle in more detail.

Ramps and slopes

It would be impossible for the man in figure 3.11 to lift the drum off the ground into the car. But it is relatively easy for him to roll it up the slope into the car, as the photo shows.

Experiment 3.5 investigates the ramp in more detail.

As mentioned earlier, the ordinary stairway is a ramp. The more gradual the slope of the stairway, the smaller the effort required to walk up it. Sometimes the stairway is a zig-zag, especially when it is in a building with a large number of storeys. Fire-escape stairs often zig-zag down the outside of a building from one floor to another.

One of the most interesting arrangements of stairs is shown in figure 3.13. This is a spiral staircase and is used where space is very limited or where a special effect is desired.

The spiral stairway is really a giant screw. The invention of the screw is attributed to Archimedes, about 2000 years ago. He developed it to wind water up from the river Nile to irrigate fields along its banks. Today the screw is used everywhere. Applications range from wood screws and nuts and bolts to corkscrews and post-hole diggers.

The screw is a force magnifier. It is difficult to crush a match box between the middle finger and thumb but quite easy if you screw on to it, as shown in figure 3.15. The machine in figure 3.15 is called a G-clamp. The distance between the threads of this clamp is 1 mm. This means that one complete turn pushes the end of the screw 1 mm into the match-box. To make one full turn of the screw, the finger moves around through a distance of 15 cm (150 mm). The ratio of

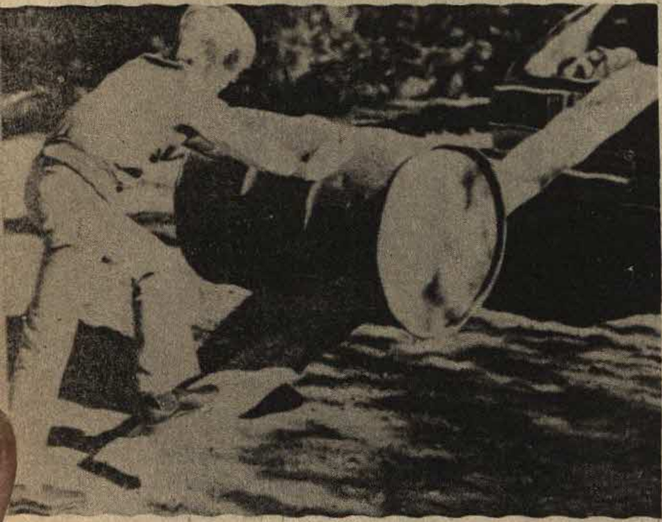


Figure 3.11: Rolling a barrel up a ramp is much easier than lifting it vertically off the ground. The ramp is a force-magnifying machine. You trade a long movement for a small effort.

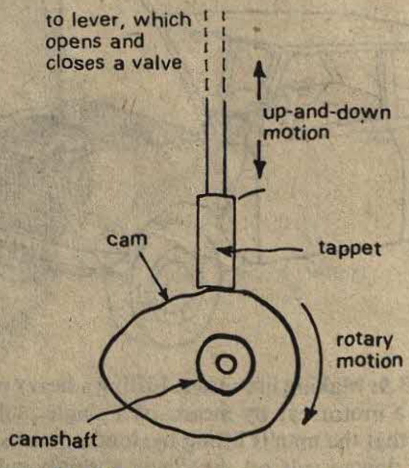


Figure 3.12: The cam acts as a rotating slope. It changes rotation into up-and-down motion. The diagram shows how cams are used in a motor-car engine to open and close valves. The valves admit petrol vapour and allow exhaust fumes to escape.

150 to 1 shows how much a screw can magnify an effort. In this particular screw the magnification would be something less than 150 because the finger has also to push against friction in the thread.

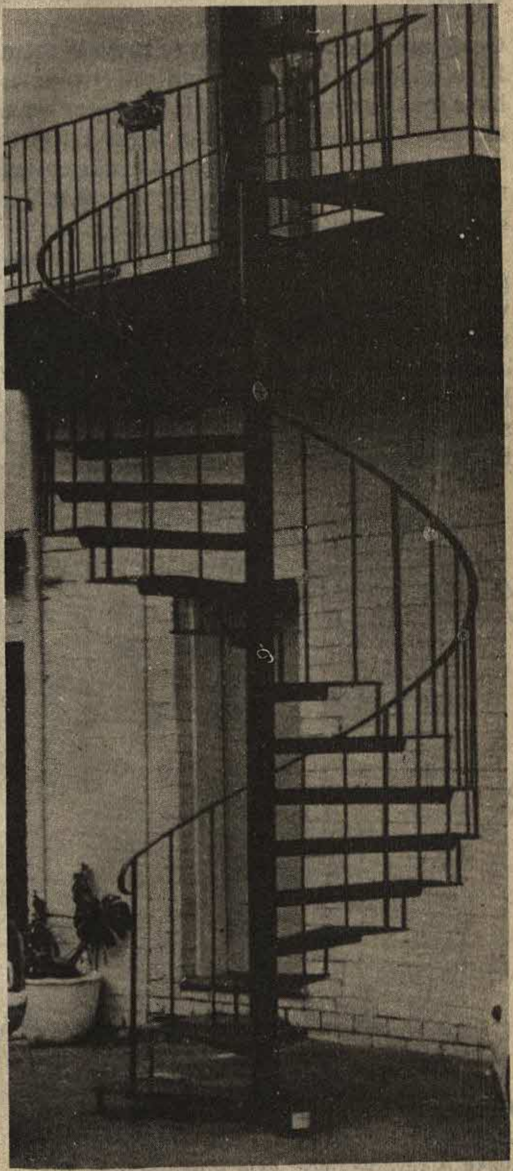


Figure 3.13: A spiral stairway is sometimes used in confined spaces. It requires less effort to go up the stairs than to climb a ladder.

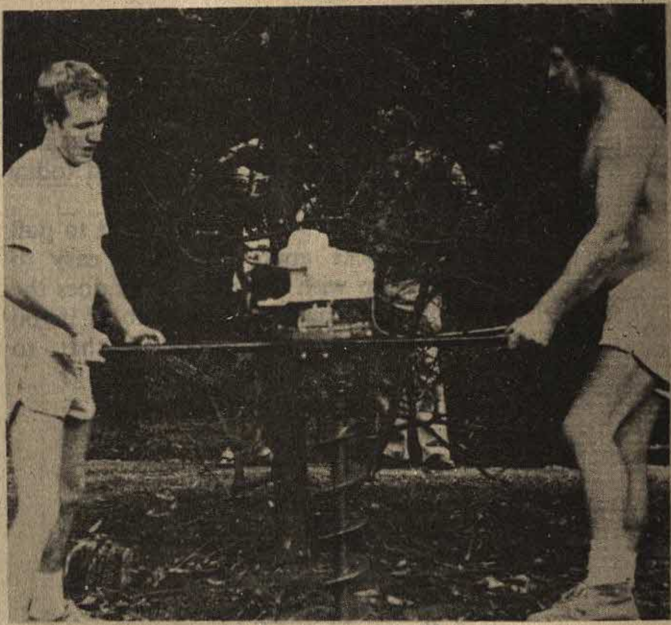


Figure 3.14: A post-hole digger — an example of a screw.

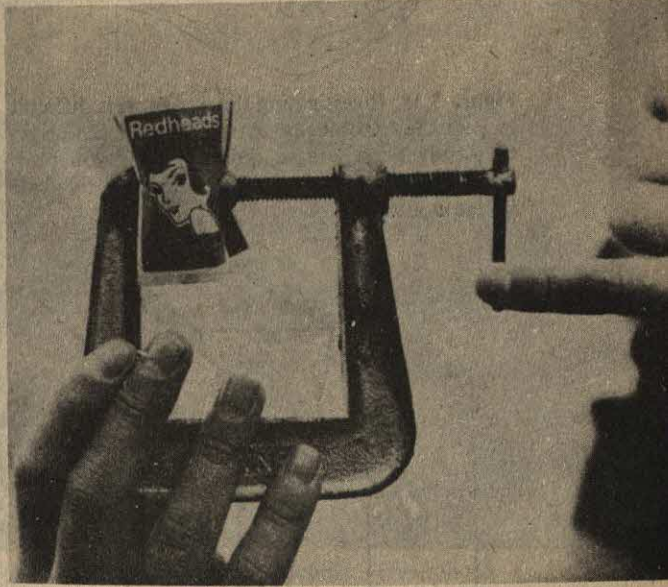


Figure 3.15: Crushing a match-box with one finger in a G-clamp. In this particular clamp the screw is moved forward only 1 mm when the finger moves round in a full circle as shown.

The wedge

The wedge is probably one of the oldest machines used by the human race. Early Stone-Age people used flint wedges and axeheads. The commonest wedges used today are the knife and the chisel.

Look at figure 3.16. It is difficult to pull the two blocks apart but quite easy to separate them with a wedge. Why does the wedge multiply the force applied to it? If you look at figure 3.17 you will see that, to separate the blocks by 2 cm, the wedge would have to be pushed down 6 cm. In other words, a wedge works because it is longer than it is thick. You are trading a distance loss for a force gain.

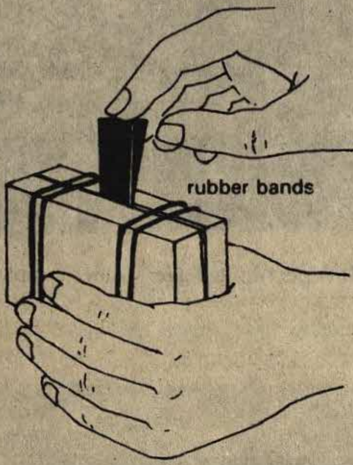


Figure 3.16: Investigating the wedge. It is difficult to pull the two blocks apart by hand. However, they may be separated quite easily if you push down on the wedge as shown — particularly if the wedge is smooth.

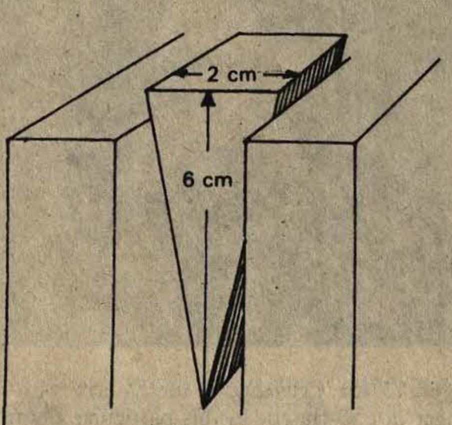


Figure 3.17: The wedge has to be pushed down 6 cm to separate the blocks by 2 cm.

Gears

Gears are wheels with teeth to prevent them from slipping. In figure 3.18 the two axles have the same diameter. Axle B rotates twice as fast as axle A. Therefore, if the effort is applied to axle A the system is a movement magnifier. If the effort is applied to axle B it is a force magnifier.

Look at figure 3.19. An arrangement of gears like this is sometimes called a crown-wheel and pinion. This is the type of gearing used to drive the rear wheels of a car. In a car, the wheels would be connected to the large gear wheel (the crown-wheel) while the shaft from the engine would be connected to the small gear wheel (the pinion).

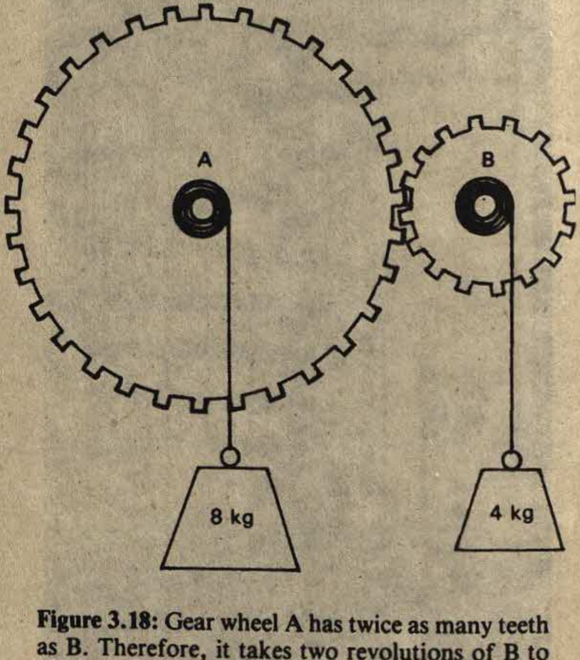


Figure 3.18: Gear wheel A has twice as many teeth as B. Therefore, it takes two revolutions of B to make A revolve once; axle B will move twice as fast as axle A. Therefore, if the effort is applied to B the apparatus is a force magnifier, and if it is applied to A the apparatus is a movement magnifier.

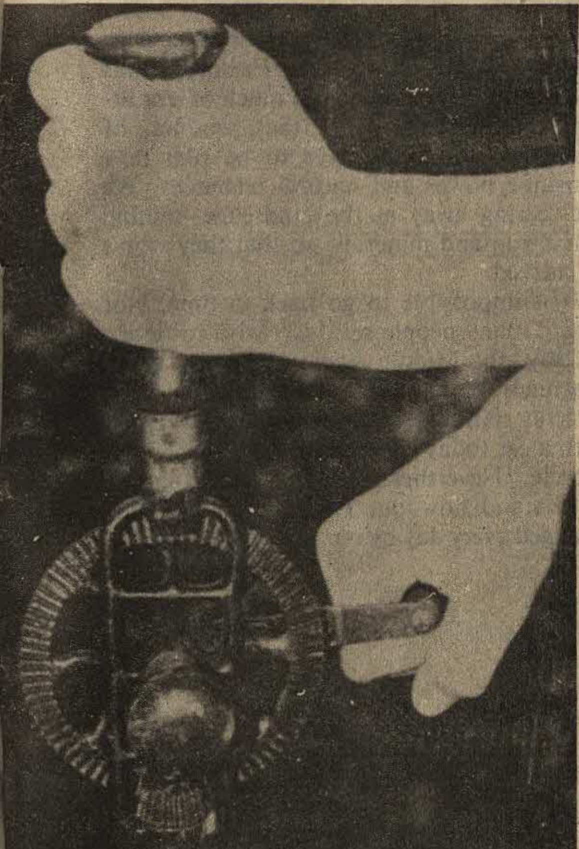


Figure 3.19: The hand drill. Do the gears magnify force or movement?

Another type of gearing is shown in figure 3.20. This is a combination of a screw and an ordinary gear wheel. The screw is sometimes referred to as a worm gear.

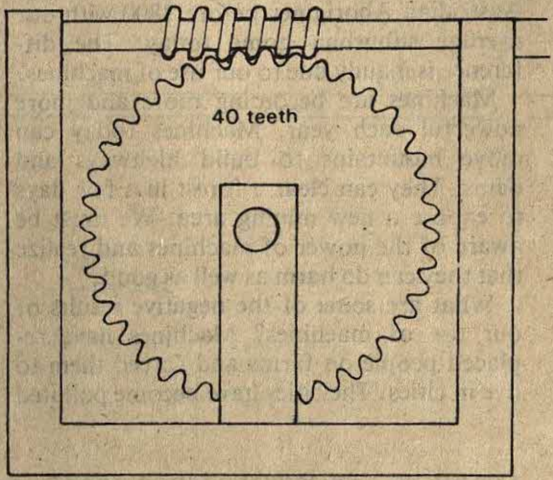


Figure 3.20: The worm gear. This gear has a very large mechanical advantage and therefore a very small movement ratio. One complete turn of the top gear moves the bottom wheel only $\frac{1}{40}$ of a revolution.

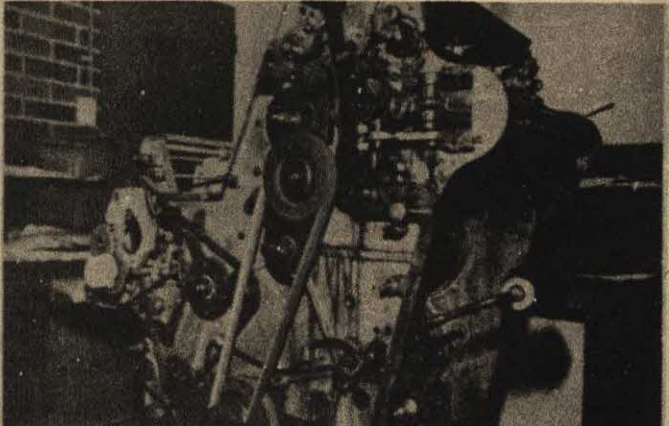


Figure 3.21: A complex machine. This photo shows one side of a school's offset printing machine. Notice the lever at the top, the worm gear at the side and a cam below it. Note also the numerous pulleys and gear wheels towards the bottom.

Machines and our environment

Machines have given us a high standard of living. Compare the shelters used by the Australian Aborigines before 1800 with our average suburban home today. The difference is mainly due to our use of machines.

Machines are becoming more and more powerful each year. Machines today can move mountains to build highways and dams. They can clear a forest in a few days to expose a new mining area. We must be aware of the power of machines and realize that they can do harm as well as good.

What are some of the negative results of our use of machines? Machines have replaced people on farms and forced them to live in cities. The cities have become polluted by the average person's most expensive machine — the motor car. Packages, tins and bottles, which make up much of our litter and garbage, are the product of machines. Machines have to be fed; they consume power and natural resources. We are tearing away at the landscape, mining petroleum and minerals, so that they won't be starved.

It is impossible to go back in time. Nor would many people seriously wish to return to, say, the Middle Ages. (Actually, many machines were in use by that time.) And it is wishful thinking to imagine that everyone with a car today is going to exchange it for a bicycle. Nevertheless, it is important to understand how our environment is being changed every day by our use of machines.

EXPERIMENT

3.1

Investigating the second kind of lever

Each group will need:

- metre ruler with holes drilled along its length
- retort stand
- nail, cork and boss-head, or capstan block and pin
- half a house brick (the load)
- spring balance (0–2 kg or 0–20 N)
- string

What to do

- Draw this table in your workbook.

Load	Load arm	Load × load arm	Effort	Effort arm	Effort × effort arm

- Fix the nail or pin to the retort stand and fit the end of the ruler on to the nail.
- Tie the string around the brick, finishing with a loop so that the brick can be hung from the ruler. Weigh the brick on the balance and record its weight in the table.
- Loop the string from the brick on to the ruler.
- Make a second loop with the string and slide it also on to the ruler.
- Slide the brick up close to the nail (the fulcrum) and attach the balance to the loop, as in figure 3.22.

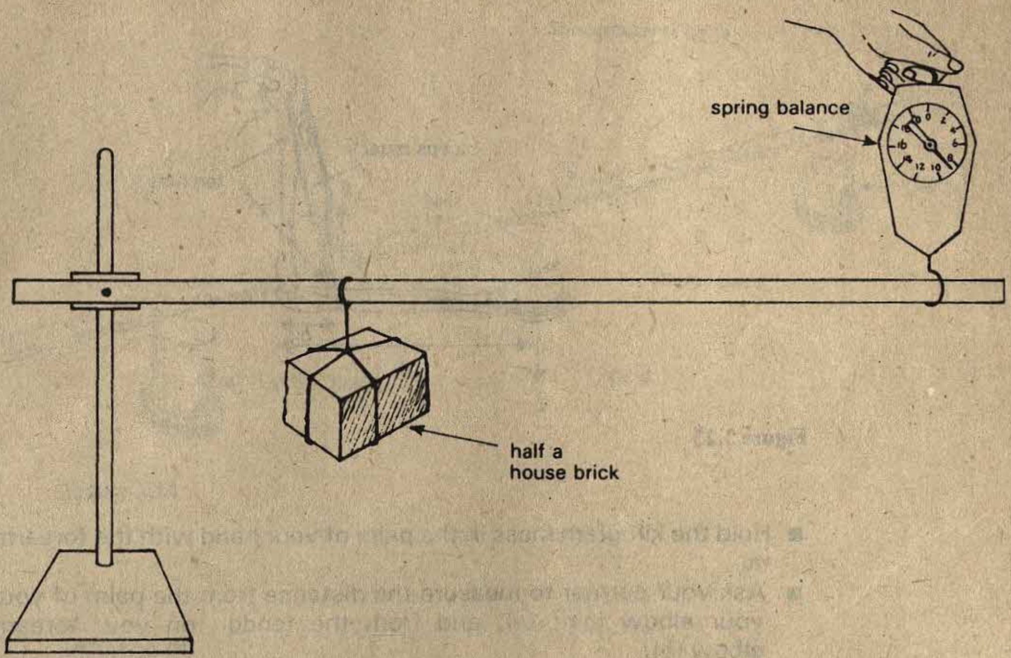


Figure 3.22: Investigating a second-order lever.

- Measure the force indicated on the balance (the effort) and record it in the table.
- Measure the distance from the fulcrum to the effort and from the fulcrum to the load.
- Repeat the experiment by placing the load in a different position.
- Repeat again, this time changing loads with another group.

Questions

3.1 When did you get the greatest magnification of effort? What was this magnification? The magnification is called the mechanical advantage of the lever.

3.2 What do you notice about the numbers in the third and sixth columns? Were they equal each time you did the experiment? If they were not equal, can you suggest a reason for the difference?

EXPERIMENT

3.2

What effort do your muscles exert when you lift a kilogram in the palm of your hand?

Each person will need:

- a metre ruler
- a kilogram mass

What to do

- Roll up your sleeve and feel the tendon of the biceps muscle near the bone of your forearm.

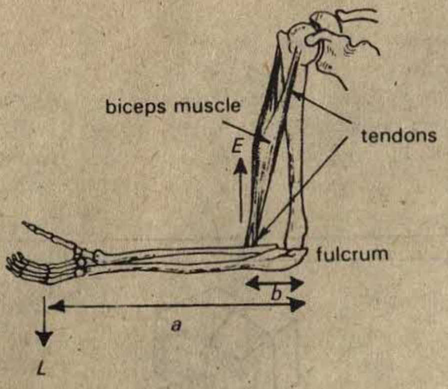


Figure 3.23

- Hold the kilogram mass in the palm of your hand with the forearm horizontal.
- Ask your partner to measure the distance from the palm of your hand to your elbow joint (*a*), and from the tendon on your forearm to the elbow (*b*).
- Using your experience in doing experiment 3.1, estimate the effort your muscle exerts in supporting a kilogram in your hand.

Questions

3.3 What effort did the muscle exert? This is only part of the total effort exerted by this muscle. Why?

3.4 Is your forearm a force magnifier or a movement magnifier? What is the ratio $\frac{\text{distance load moves}}{\text{distance effort moves}}$?

3.5 The action of your biceps muscle is an example of the third kind of lever. The same principle is used to move many of the bones in your body. Feel the muscles of your jaw as you bite. Where is the fulcrum of this movement, and where are the tendons attached? Work out the movement magnification. Work out which order of levers the movement of your fingers can be classified as.

EXPERIMENT

3.3

What is the weight of a fly?

Each group will need:

- narrow strip of balsa of uniform width and thickness
- three corks
- razor blade
- 100 small pins
- a fly
- beam or electric balance

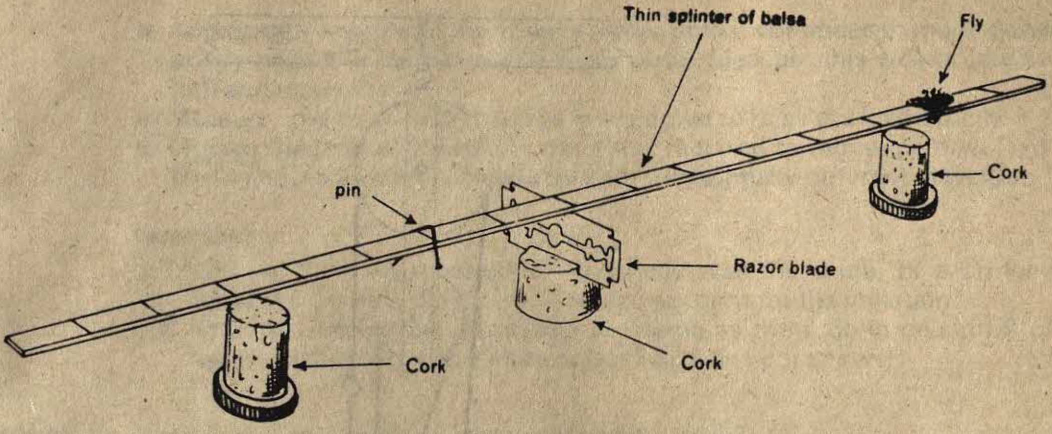


Figure 3.24

What to do

- Weigh 100 pins (this could be a class activity). Calculate the weight of 1 pin.
- Balance the balsa strip on a razor blade, as shown in figure 3.24. Mark it off in centimetres either side of its balance point.
- Place the balsa strip back on the razor blade with two additional corks underneath the ends of the strip to reduce its up and down movement.
- Place the fly on one end of the strip.
- Place a pin on the other side of the strip, moving it one way or the other so that it just balances the fly.
- Calculate the weight of the fly.

Question

3.6 What was the weight of the fly?

EXPERIMENT 3.4

Investigating a block and tackle

Each group will need:

- one block with two pulleys
- a single pulley
- half a house brick, and other objects to act as the load
- length of strong thread, and string
- wooden beam between two stools or two retort stands
- weight carrier and various slotted weights (see figure 3.25)
- spring balance to measure load and effort
- metre ruler

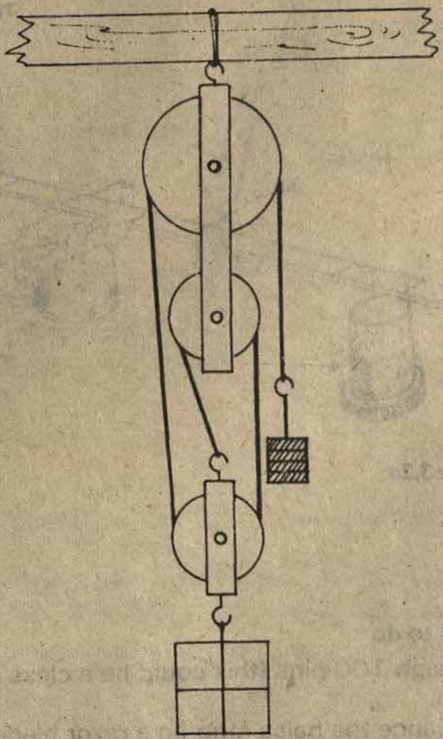


Figure 3.25

What to do

- Draw the following table in your workbook.

Load (L)	Effort (E)	M.A. $= \frac{L}{E}$	Distance load moves up (a)	Distance effort moves down (b)	$\frac{b}{a}$

- Tie the string around the load so that it can be attached to a hook.
- Measure the load on the spring balance and record this weight in the table.
- Attach the double-pulley block to the wooden beam with string or hooks.
- Cut off the length of thread that you estimate will be needed to set up the system shown in figure 3.25.
- Set up the machine as shown.
- Make a loop at the free end of the string in order to attach the weight carrier.
- Attach the load to the bottom block.

- Add slotted weights to the weight carrier until it continues to move down slowly once it is started with a slight push. Measure this weight (the effort) and record it.
- Measure how far the effort has to move down to raise the load 10 cm.
- Change the load and measure the effort required to move the new load. Try to choose a variety of loads that are substantially different in weight.

Questions

3.7 Did you find the mechanical advantage was the same for each load lifted? If not, how did it vary? Can you account for the variation?

3.8 Was the mechanical advantage the same as the ratio in column 6 of your table? If not, was it more or less? Explain your answer.

EXPERIMENT 3.5

What is the mechanical advantage of using a ramp?

Each group will need:

- a roller, trolley or model cart
- piece of smooth wood about 80 cm long
- a spring balance to measure forces
- a piece of string
- a metre ruler

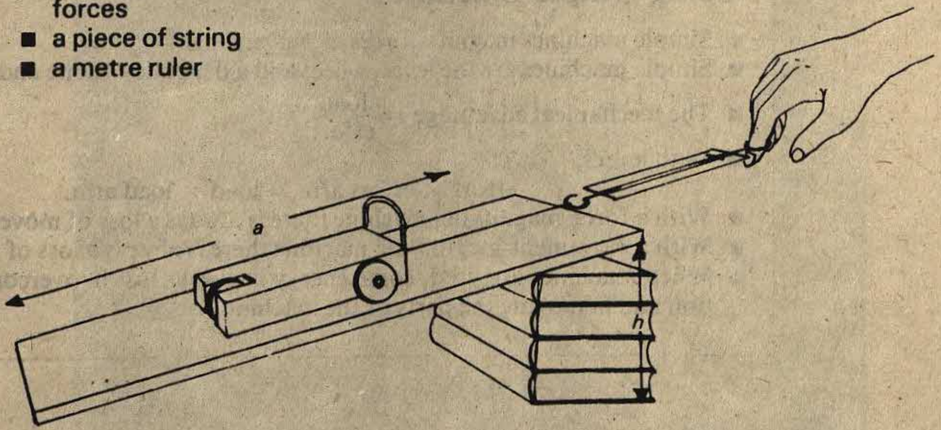


Figure 3.26

What to do

- Copy this table into your workbook.

Weight of roller (L)	Effort (E)	M.A. $= \frac{L}{E}$	Length of ramp (a)	Height of ramp (h)	$\frac{a}{h}$

- Measure the weight of the roller with the spring balance.
- Set up the ramp as shown in figure 3.26, making the height (*h*) = 10 cm. This gives a slope of 1 in 8.
- Place the roller on the ramp and measure the force needed to just move it up the slope.
- Repeat the experiment making *h* equal to 20, 30 and 40 cm. Record your results.
- Draw a graph plotting *E* against *h*.

Questions

3.9 What force was needed to pull the roller up these slopes:
- vertical?
- 1 in 8?
- 1 in 4?
- 1 in 2?

3.10 Is the ramp a force magnifier or a movement magnifier?

Using simple machines

- Simple machines magnify forces or movements.
- Simple machines are the lever, wheel and axle, pulley, slope and screw.
- The mechanical advantage $= \frac{\text{load}}{\text{effort}}$.
- With levers,
  $$\text{effort} \times \text{effort arm} = \text{load} \times \text{load arm}.$$
- With a force-magnifying machine there is always a loss of movement.
- With a movement-magnifying machine there is always a loss of force.
- When machines are used, some energy is always lost in overcoming friction and in moving the parts of the machine.

Spelling list

Aborigines
axle
bicycle
develop
fulcrum
lever
magnifier
magnify
muscle
pulley
spiral
tackle
tendon
trolley
wedge

Things to do

3.11 Examine a manual typewriter. What order of levers is used to move the type? Is it a force magnifier or a movement magnifier? Can you find a third order lever on the machine? Is there a wheel and axle? Where? Are there any pulleys?

3.12 Obtain a set of gears, rods and supporting blocks from a Lego set. Set them up using pairs of gears of different sizes. Test the force required to turn one axle and the resistance that can be felt on the other.

3.13 Use two pieces of dowel and a length of cord to pull four people together as shown in figure 3.27.

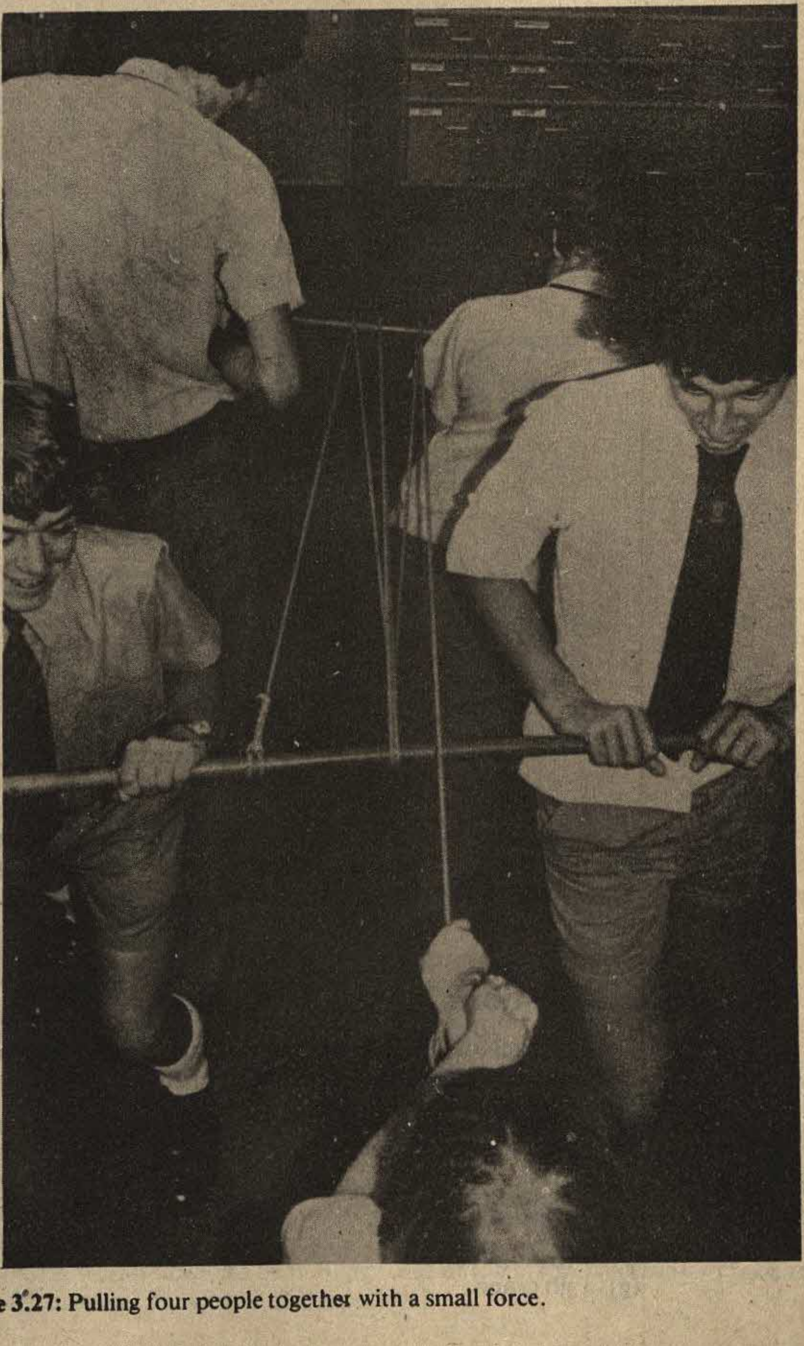


Figure 3.27: Pulling four people together with a small force.

3.14 Turn a bicycle upside down and compare the movement of the pedal with the movement of the rim of the road wheel. Use the gears and find out how they change this ratio.

3.15 Set up a set of pulleys as shown in figure 3.28. Work out the mechanical advantage. Compare this with the movement ratio of the effort and load.

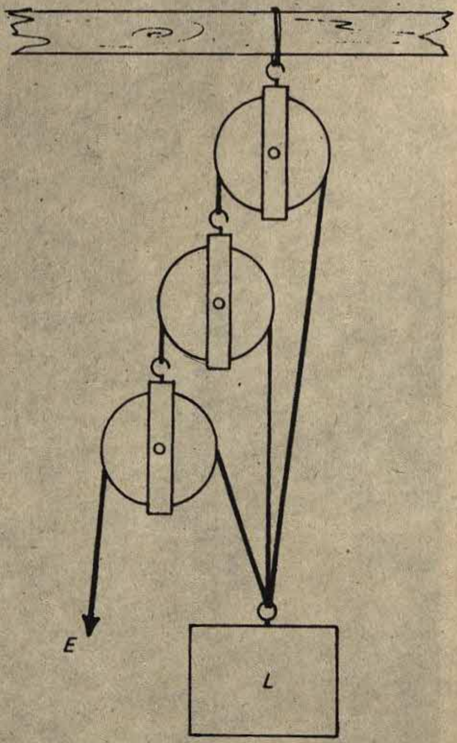


Figure 3.28

3.16 Examine a car jack. Compare the movement of the hand and of the part of the jack that lifts the car. The ratio of these two movements will give you some idea of the mechanical advantage. Will it be more or less than this ratio?

More questions

3.17 Classify each of the following as particular simple machines. State whether each machine magnifies force or movement.
(a) the steering wheel of a car
(b) a pair of scissors
(c) an axe
(d) a pair of pliers
(e) a door knob
(f) a fishing rod
(g) a jib crane.

3.18 The Great Pyramid of Egypt is 140 metres high. It is said that 100 000 slaves were employed for 20 years to build it. How did they move the huge blocks of stone into position? Remember that only a few of the simple machines were used at that time (about 2500 B.C.). (R)

Test yourself (chapter 3)

Write the answers in your workbook.

1. A girl weighing 40 kg is seated 2 m from the fulcrum of a seesaw. Her friend weighs 32 kg. Where must the friend sit to balance?
2. List the following as force magnifiers or movement magnifiers: (a) pliers, (b) chisel, (c) screw, (d) bottle-opener, (e) scissors, (f) egg-beater, (g) spade as used when shovelling soil.
3. Why is a screwdriver a force magnifier?
4. A car changes into low gear to go up a steep hill. Does the change produce a magnification of force or of movement?

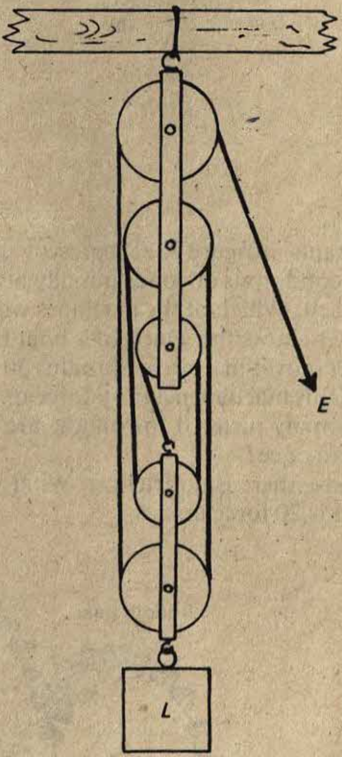


Figure 3.29

5. Look at figure 3.29. Set up the system for yourself.
   (a) How far does the load move up when the effort moves down 100 cm?
   (b) Suppose the system is frictionless and the pulleys practically weightless. What is the maximum load that could be lifted by a man who weighs 80 kg?
   (c) What would this load be if 10 per cent of the effort were wasted because of friction and the weight of the pulleys?

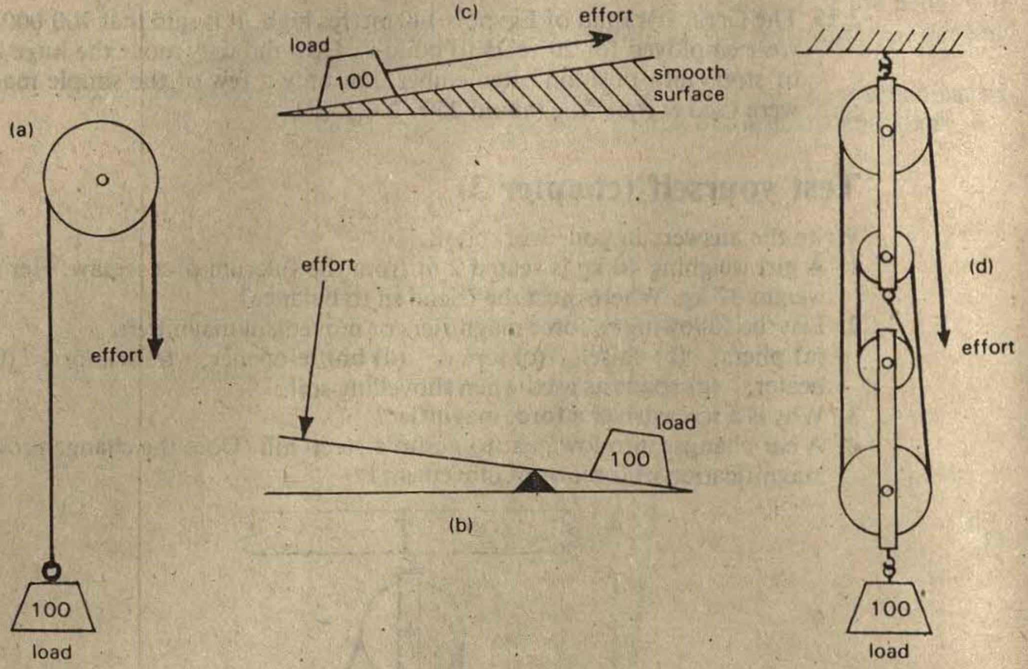


Figure 3.30

6. The diagrams in figure 3.30 represent simple machines working under normal practical conditions on loads initially at rest. An effort of 100 force units is applied to each. Which of the machines would move the load?
7. Figure 3.31 shows the winch of a boat trailer. The drum has a radius of 5 cm. The effort moves in a circle of radius 30 cm.
   (a) Does this machine magnify force or movement?
   (b) How many turns of the handle are required to move the large gear wheel around once?
   (c) Suppose there is no friction. What would be the pull on the rope when the effort is 20 force units?

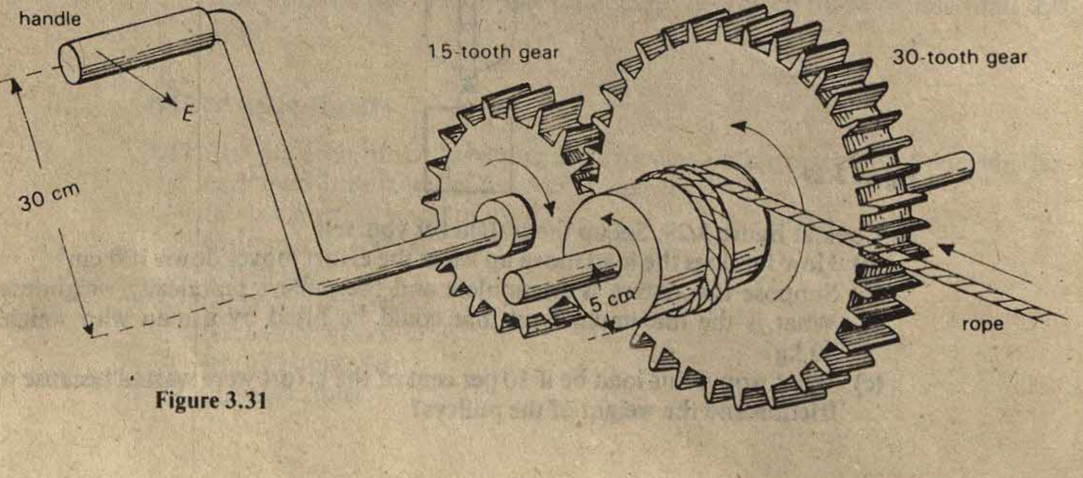


Figure 3.31

8. Everyone realizes that some machines are very powerful and, if their use is uncontrolled, can cause unwanted destruction of the environment or harm to the people of the community. The best answer to this problem is:
   (a) Everyone should leave the control of such machines to local councils and government officials.
   (b) People should see that schools teach children about the need to care for the environment and the quality of life in the community.
   (c) Everyone should take a close personal interest in the decisions of councils and government officials.
   (d) The government should ban the construction of all machines beyond a certain size.

4

The skeleton

Some animals, such as worms and jellyfish, have no skeletons. Without a skeleton an animal's ability to move from place to place is very limited. Liberate a mouse and a worm on a lawn and notice the time it takes each animal to get away and hide. Have you ever seen a jellyfish pushing itself through water? Compare its speed of movement with that of a fish when it darts away from danger.

The skeletons of aquatic animals are much smaller and lighter than those of land animals. Compare the skeletons of a whale and a horse (figures 4.1 and 4.2). The weight of a whale is supported by the water. It doesn't need a large, strong skeleton like the horse's. But think how helpless a whale is if it is stranded on a beach. Its body sags, a helpless mass on the sand. Its fins and tail, which can move it so rapidly through the water, are powerless to lift it and move it over the land.

As well as providing support and assisting movement, the skeleton protects the body of

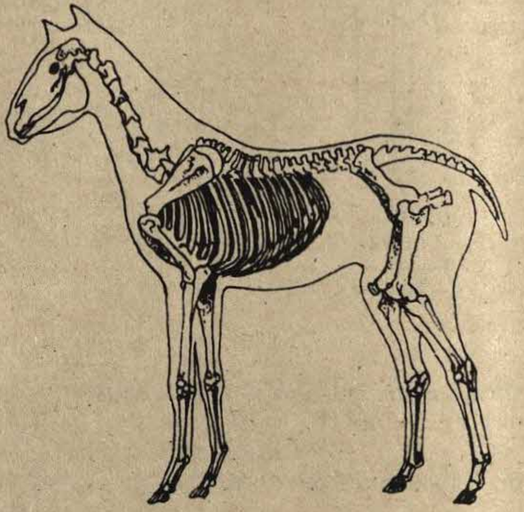


Figure 4.2: The horse has a large skeleton with strong limb bones and muscles. These are needed to support the animal's body and to give it the power to move rapidly over the land.

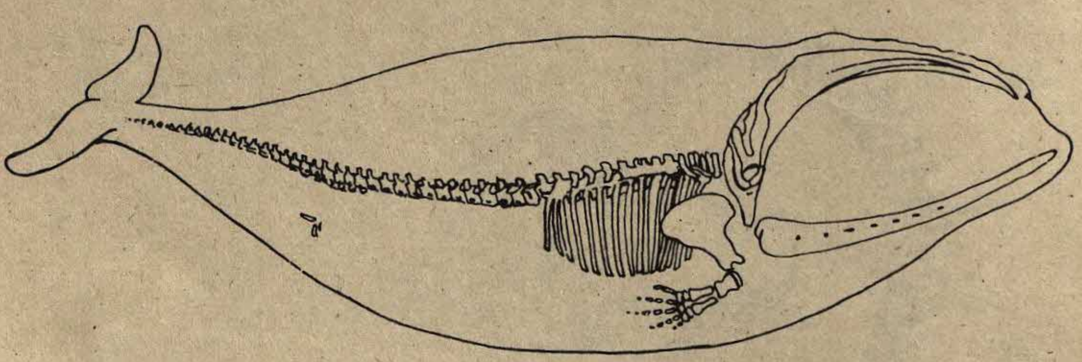


Figure 4.1: The whale has a small skeleton compared with the size of its body. The whale's weight is supported by the water. This makes large-boned limbs unnecessary. Actually, large limbs would only hinder the whale's movement through the water.

the animal. For example, the skull protects the delicate tissues of the brain and the ribs protect other vital organs, the heart and the lungs.

The parts of the skeleton

The human skeleton has more than 200 separate bones. Bone itself contains both soft and hard material. Examination of a large, uncooked beef bone cut in halves along its length shows this quite clearly. (See figure 4.3.)

The hard material of a bone (sometimes called "bone salts") is mainly solid calcium phosphate. The amount of these calcium salts in a bone affects its strength. The bones of young children contain less calcium salts than do adults' bones, and so are more flexible. In aged people the situation is reversed. Their bones tend to break easily because they contain less soft material.

The soft material occurs as fibres of protein in the spaces between the solid material. These fibres contain live cells, which enable the bone to mend should it be broken. They also make the bone less brittle and thus less likely to break.

The inside of some bones is hollow. Hollow bones are almost as strong as solid bones and in addition are much lighter. The hollows of some bones contain marrow. In this marrow new blood cells are continually being made.

Cartilage is another important material in the skeleton. It is tough and strong but not as rigid as bone. It is the material we call gristle. The main function of cartilage is to absorb shock. For example, the thin layer of cartilage covering the smooth ends of many bones acts as a cushion to prevent jarring.

Figure 4.4 is a diagram of the human skeleton. It shows the main parts — the vertebral column, the skull, the ribs, the limbs and their supports. It also shows those positions where cartilage is found.

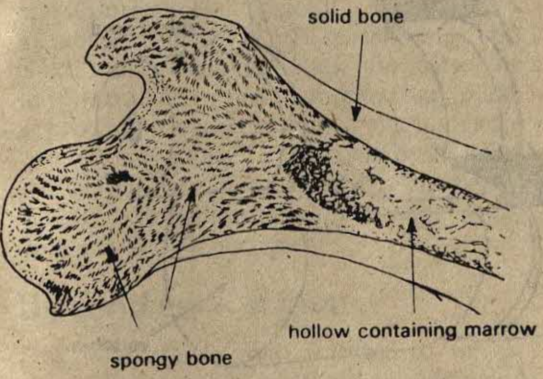


Figure 4.3: A section through one end of a large bone showing both hard and soft parts. The soft parts are a lace-work of hard bone filled in with red living tissue.

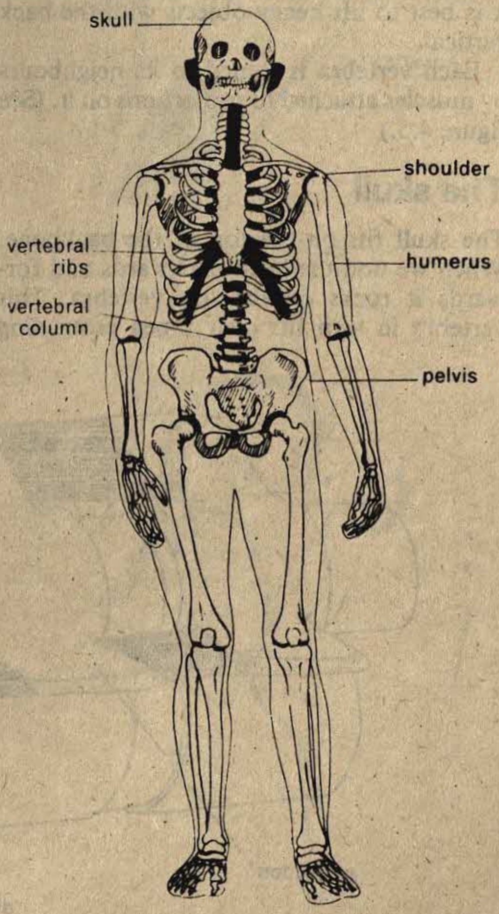


Figure 4.4: The human skeleton. The places where cartilage is found are shown in black.

The vertebral column

The vertebral column is the backbone. It extends from the skull to the tail bone and is something like a stout string of beads. It is made up of twenty-six vertebrae, each separated from the next by a disc of cartilage. These discs absorb most of the shocks to which the backbone is subjected.

Sometimes a disc can become dislodged and partly slip out from between two vertebrae. This is known as a "slipped disc" and it is very painful because the two vertebrae can press on nerve threads coming out from the spinal cord. A disc is most likely to be displaced when a person lifts a heavy weight with an arched back. For this reason it is best to lift heavy objects with the back vertical.

Each vertebra is joined to its neighbours by muscles attached to projections on it. (See figure 4.5.)

The skull

The skull fits on the top of the backbone. When we nod the head backwards and forwards it rocks on the top vertebra. This vertebra in turn fits over a peg protruding from the one beneath it. When we turn the head right or left, the skull and the top vertebra rotate on this peg.

The main function of the skull is to enclose and protect the brain. The skull also supports and protects the eyes, the ears and the nose. It consists of twenty-two bones. Most of these are held rigidly together by jagged interlocking edges. (See figure 4.6.)

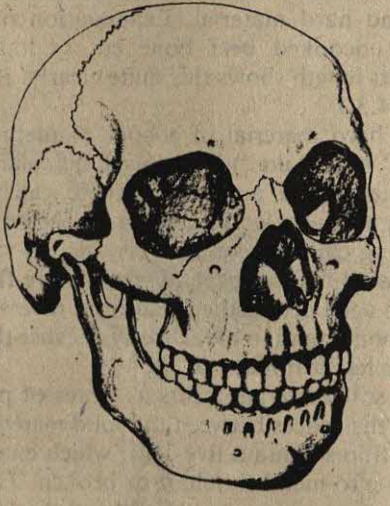


Figure 4.6: The human skull.

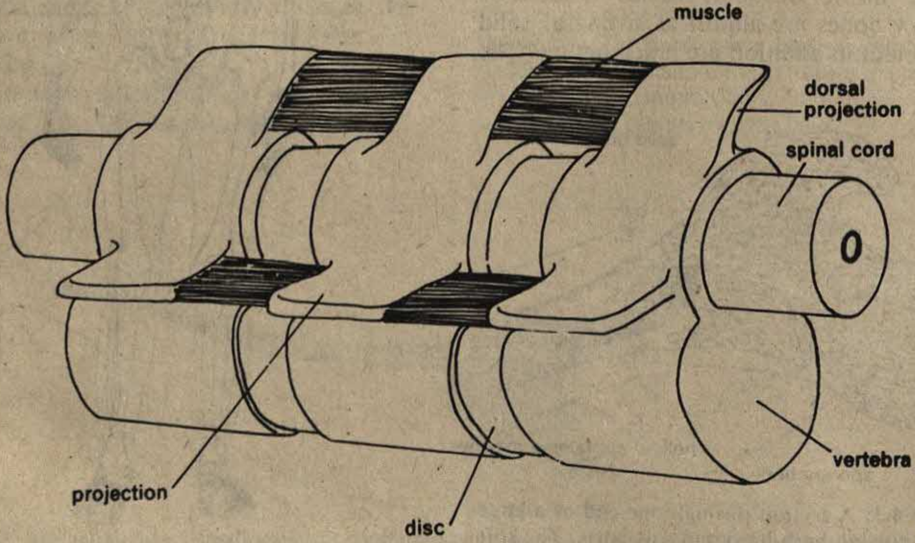


Figure 4.5: Diagram showing how vertebrae are connected. The spinal cord runs through an opening in each vertebra.

In a baby these edges are separated. They fuse together when the skull has grown to its full size. The only movable part of the adult skull is the lower jaw.

The ribs

Each vertebra at the back of the chest has a pair of ribs attached to it. These extend around the chest and some join the breast bone at the front. (See figure 4.4.) The ribs enclose and protect the heart and lungs.

During breathing the ribs move. This movement is controlled by muscles joining them.

The limb supports

The shoulders are the supports for the arms; the hips are the supports for the legs. Each shoulder is joined to the skeleton by a collarbone, which is fixed at the top of the breast bone. Each hip is attached to the lower region of the backbone. (See figure 4.4.)

Joints

Some joints, such as those in the skull, do not allow any movement at all. Most joints, however, allow some movement. Figure 4.7 shows a typical movable joint. Cartilage lines the ends of the bones to reduce friction and absorb shock. The joint is enclosed by a membrane that produces a special fluid. This fluid, called synovial fluid, lubricates the joint. Damage to this membrane may make it produce too much fluid and thus cause "water on the knee". The bones at the joint are bound firmly together by ligaments. Should these ligaments be damaged, dislocation of the bones may occur.

Ball and socket joint

This joint allows great freedom of movement. The shoulder joint and the hip joint are ball and socket joints. In the shoulder joint the rounded head of the humerus fits into the hollow socket of the shoulder blade. (See figure 4.4.) Figure 4.8 shows how, in the hip joint, the round end of the femur fits into a hollow socket in the pelvis.

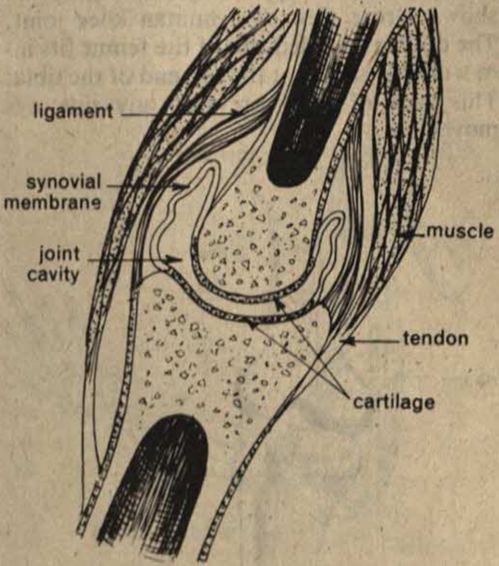


Figure 4.7: Typical movable joint.

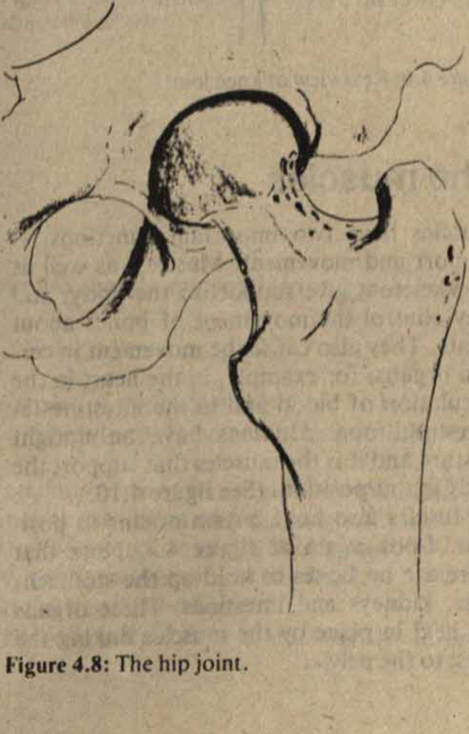


Figure 4.8: The hip joint.

Hinge joint

The hinge joint allows movement in one plane only. The knee and elbow are typical examples of this type of joint. Figure 4.9 shows a rear view of a human knee joint. The double rounded end of the femur fits into a double socket at the top end of the tibia. This type of joint prevents any sideways movement.

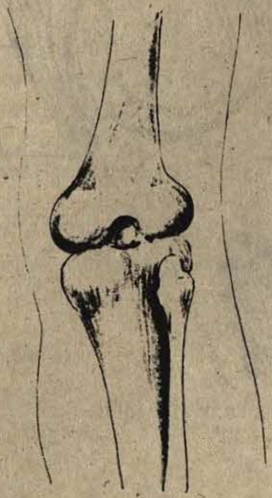


Figure 4.9: Rear view of knee joint.

The muscles

Muscles have two important functions — support and movement. Muscles, as well as the skeleton, give support to the body, and they control the movement of bones about joints. They also cause the movement in certain organs, for example, in the heart in the circulation of blood and in the intestines in digesting food. Humans have an upright posture and it is the muscles that support the body in this position. (See figure 4.10.)

Muscles also hold certain organs in position. Look again at figure 4.4. Note that there are no bones to hold up the stomach, liver, kidneys and intestines. These organs are held in place by the muscles linking the chest to the pelvis.

Muscles and bones act together to produce the movements of the limbs and body. Muscles in the limbs are composed of large numbers of long thin cells. They are attached to the bones by tendons. You can feel some

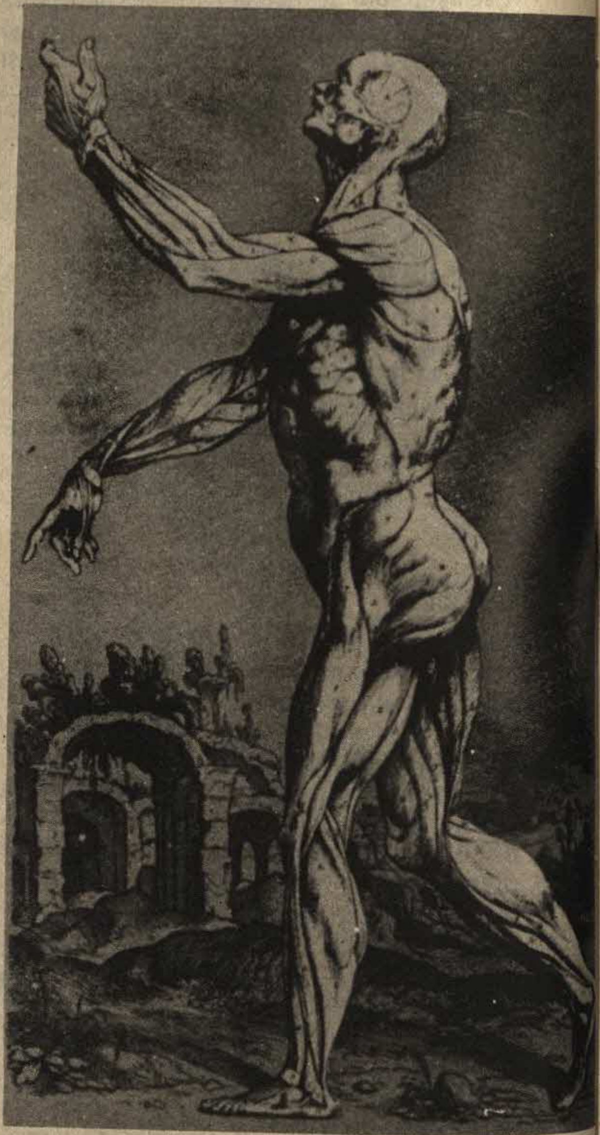


Figure 4.10: The muscles of man, as drawn by Andreas Vesalius in a book published in 1543. This remarkable book contained over 300 anatomical drawings. They are so detailed and accurate that they are still being used today.

of these tendons if you run a finger across the inside of a person's wrist.

Muscle cells are stimulated by electrical impulses from the brain. These impulses cause the muscle to thicken and shorten so that it pulls on the bone and thus causes movement about the joint.

Muscles linked to limbs cannot exert a push. They can only pull. Therefore, each moving part of the body must have at least two muscles to work it. When one muscle is thickening and pulling, the other muscle is relaxed and allowing itself to be stretched.

Figure 4.11 shows how this pairing of muscles works the lower arm about the elbow. The biceps muscle contracts to bend the arm while the triceps muscle contracts to straighten it. You can feel these muscles contract yourself by first attempting to lift a bench with your hand beneath it, and then pressing down on the bench top with your arm well bent. Feel the biceps and triceps in both actions.

No discussion about limbs and muscles would be complete without mentioning the human hand. The hand has a feature that has helped the human species to its present position of dominance over all other life on earth. This feature is the *opposable thumb*. It is the ability of the thumb to touch the tips of the other four fingers. If you think about it, you will realize that it is this feature that gives the human hand its great dexterity.

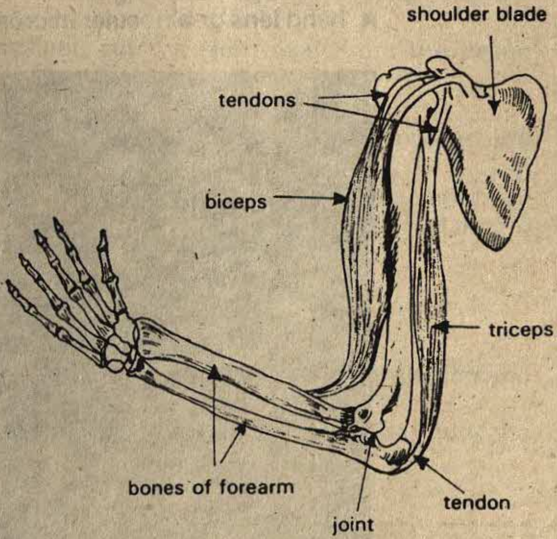


Figure 4.11: The muscles that move the lower arm about the elbow.

EXPERIMENT 4.1

Examining a human skeleton

Each group will need:

- a human skeleton (Plastic models are readily available from most school suppliers.)

What to do

- Locate the areas where cartilage is part of the skeleton.
- Identify the limb supports and note where they are connected to the backbone.
- Locate and examine the ball and socket joints at the shoulders and hips.
- Locate and examine the hinge joints at the knees and elbows.
- Note the variety of shapes and sizes of vertebrae in the backbone.
- Locate the vertebrae concerned with the movement of the skull.
- Note the large number of bones in the hands and feet.
- Note the way the big toe moves and compare this with the way the thumb moves.

EXPERIMENT 4.2

Dissecting a frog to examine the muscles in the rear legs

Each group will need:

- a freshly killed frog
- dissecting scissors, forceps, probe and scalpel
- board
- thread and drawing pins
- hand lens or binocular microscope

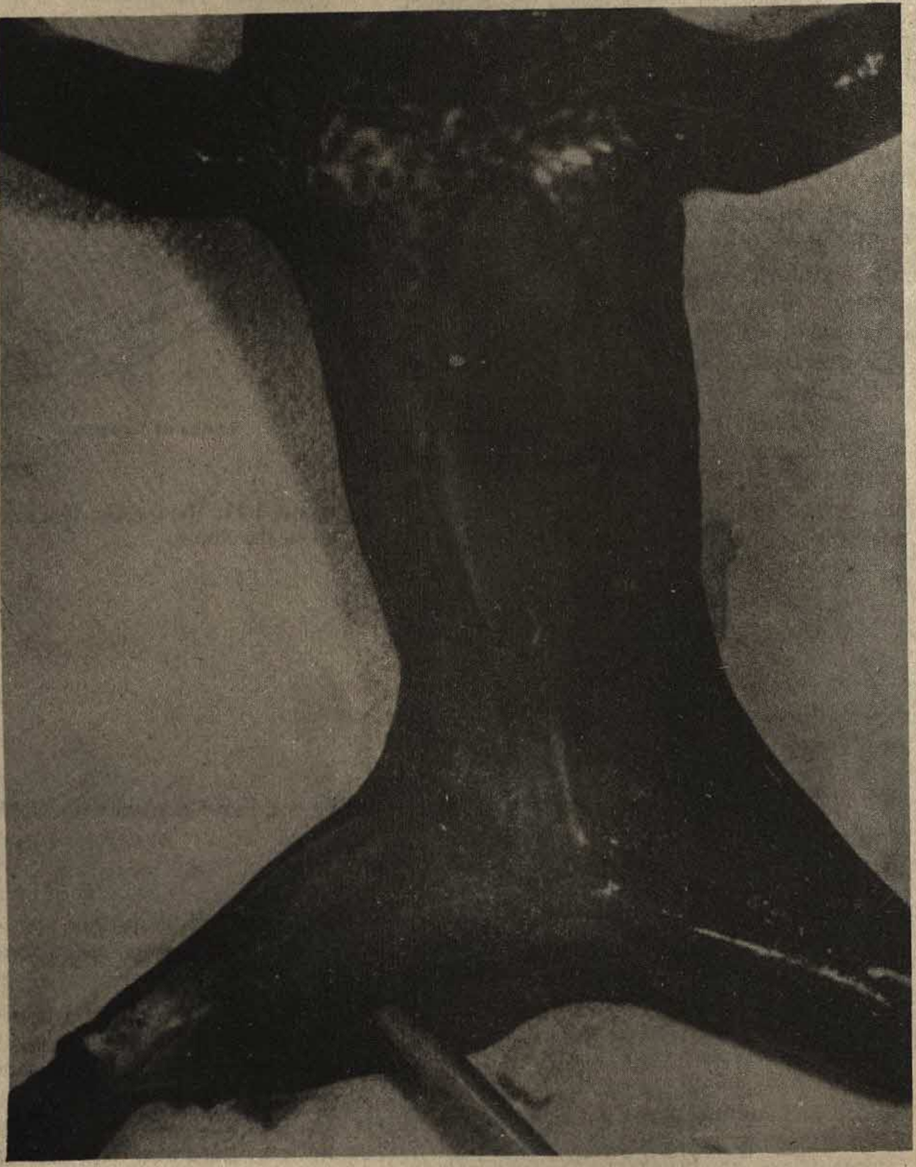


Figure 4.12: Showing how to dissect a frog so that the muscles of the legs are exposed.

What to do

- Stretch the frog out on its back on the board.
- Hold it in this position using thread tied to its limbs. Fasten the ends of the thread with drawing pins.
- Lift the skin of the abdomen with forceps and make a cut up the centre of the body with the scissors.
- Lifting it as you do it, cut the skin along the length of the leg with the scissors.
- Using forceps and a sharp scalpel, cut the skin away from the tissue below it.
- Lay the skin back as shown in figure 4.12.
- Carefully examine the leg, using a probe. Find out where the muscles are attached to the bones.
- Try to find a pair of muscles. Grip one muscle in your fingers and pull it up. Note the effect. Try to find the muscle that has the opposite effect on the limb when you pull it.
- Examine muscle tissue under the lens. Note its appearance.

Questions

4.1 Were you able to find a pair of muscles? Make a drawing of the leg and these muscles.

4.2 Make a drawing of a length of muscle tissue as you saw it under the lens.

The skeleton

- The skeleton
  - supports the body
  - protects vital organs
  - allows body movement.
- The skeleton is made of bone and cartilage.
- Bone contains hard non-living material and soft living material.
- The main parts of the skeleton are the vertebral column, the skull, the ribs, and the limbs and their supports.
- Two types of movable joint in the skeleton are the ball and socket joint and the hinge joint.
- The bones of the skeleton are moved by the contraction of muscles attached to them.
- Muscles help to support the body and enable the skeleton to move.

Spelling list

cartilage
femur
jar
jarring
ligament
movable
muscle
opposable
skeleton
skull
synovial
tendon
vertebra
vertebrae

Things to do

4.3 Place a long fresh sheep's bone in a measuring cylinder of dilute hydrochloric acid for about a week. Take it out and wash it. Explain what has happened.

4.4 Ask your butcher to saw a long bone in halves from end to end. Examine its structure. Notice the hollow centre and networks of spongy bone at each end. Notice the cartilage and the places where tendons were attached.

4.5 Break up a bone into small pieces. When you are breaking it, notice how strong it is. Heat some pieces on a crucible lid. Note the smell. This is burning protein. What is the white ash that is left?

4.6 Obtain a piece of ox-tail and boil it in water for two or three minutes to soften the meat. Cut away the flesh from the bones. Notice the gristly blocks holding the bones together. These are the discs.

4.7 Examine prepared slides of muscle. Notice the difference between the kind of muscle attached to limbs and the muscle of the heart.

4.8 Dissect the knee joint of a lamb or sheep. Note the parts described in figure 4.7.

4.9 Feel the tendon joining the calf muscle to the heel (the Achilles tendon). Raise your foot on to its toes. Can you feel the tightening of this tendon? Make a drawing of the foot bones and the Achilles tendon. Why was the tendon given this name?

More questions

4.10 Write down three functions of the human skeleton.

4.11 Give three examples of lever systems in the human body. In each example state where the load and the effort are applied and locate the fulcrum.

4.12 Describe two types of movable joint in the human body and compare the movements each allows.

4.13 Explain why there is little friction in the joints of the human body. (R)

4.14 What absorbs most of the jars received by the body?

4.15 Is bone dead or alive? Explain your answer.

4.16 Describe the shape of the cells in the muscles attached to the skeleton. What happens to these cells when they are stimulated? What sort of stimulation is needed?

4.17 What is "water on the knee"?

4.18 A recurring dislocation may be fixed by surgery. How do you think the joint is repaired? (R)

4.19 Suggest a reason why the vertebrae just above the hip are bigger than those in the region of the chest.

4.20 What is arthritis? How does it cause stiffness in joints? (R)

4.21 Compare the movements of the thumb and big toe of a human. Why are humans able to perform very delicate manual operations? (R)

4.22 Muscles pull rather than push on the bones. How, then, is it possible for a weight-lifter to push heavy weights above his head?

4.23 In what ways do muscles differ from tendons? (R)

Test yourself (chapter 4)

Write the answers in your workbook.

1. State the three functions of the skeleton.
2. (a) What is a common name for cartilage?
   (b) Where does cartilage occur in the skeleton?

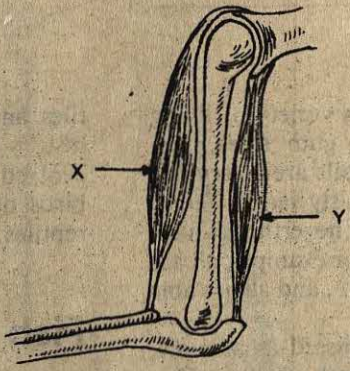


Figure 4.13

3. Figure 4.13 illustrates the elbow joint with the muscles, X and Y, that surround it. A man takes off his glasses and stretches out his arm to place them on the table. What happens to muscles X and Y as he does this?
4. It is your calf muscles that act to lever your body up on to its toes. Is this action
   (a) a force magnifier
   (b) a movement magnifier
   (c) a lever with the fulcrum at one end
   (d) a lever with the effort and the load the same side of the fulcrum?
   Answer "yes" or "no" in each part.

Choose the best answer to each of the questions 5 to 7 and write its letter in your workbook.

5. A ball and socket joint occurs in the
   (a) knee
   (b) elbow
   (c) shoulder
   (d) neck.
6. The hard, non-living part of bone is composed mainly of
   (a) marrow
   (b) protein
   (c) cartilage
   (d) calcium salts.
7. A seal is more vulnerable to predators on land than in the sea because
   (a) a seal cannot breathe properly on land
   (b) a seal's coat dries out quickly on land
   (c) a seal can see better in water than on land
   (d) its limbs are inadequate for quick movement over the land.

5

The vertebrates

There is an almost endless variety of living things on earth: whales, gum trees, seaweeds, mushrooms and snails are a very few examples. These are obviously very different from one another, but they nevertheless have a great deal in common. For example, all are made up of cells that respire, and all are able to reproduce.

Living things may be classed as animals, plants, fungi, bacteria and viruses. This chapter is about one group of animals — the vertebrates.

The vertebrates, as the name implies, are animals with backbones. The backbone contains a spinal cord that connects the brain to the various parts of the body. Vertebrates usually have two pairs of limbs, which are used mainly for moving the animal from place to place in its habitat. The limbs are called fins, wings, legs or arms according to their function.

Vertebrates themselves are classified into five large groups — fish, amphibians, reptiles, birds and mammals.

Evolution of the vertebrates

Fish are the simplest of the vertebrate groups. The first fossils of fish appear in sedimentary rocks laid down about 500 million years ago. We assume that the first fish must have appeared in the waters of the world at about that time.

Some 100 million years later, certain fish were evolved with body structures that enabled them to live both in water and on land. These animals were the first amphibians.

From the amphibians developed the reptiles and from them the birds. During the history of the reptiles the mammals also were evolved. This means that both mammals and birds developed from the one stem — the reptiles.

Fish

Fish are found wherever there is permanent water that contains enough oxygen. Over 80 per cent of the earth's surface is covered with water, so it is not surprising that there are over 20 000 known species of fish. There are all shapes and sizes, living in many different habitats. Some live near the bottom, others near the surface, some in fast-flowing streams, others in quiet backwaters, some in fresh water, others in salt water.

Fish may be observed by watching goldfish in an aquarium. (A goldfish may be held in a wet hand out of water for about five minutes without any ill effects to it.) Think about the shape of a fish while you are watching it swim. You will notice that it is beautifully streamlined. Its head is joined smoothly to the rest of its body. There is no neck or shoulders. The body is covered with scales that overlap in the one direction — away from the nose. The fish has a pair of nostrils in front of the eyes. Nostrils are generally used by animals for breathing and smelling; the fish uses its nostrils only for smelling.

Observe the fish's eyes as it swims around in the aquarium. You will see that its eyes are without eyelids. Why are eyelids unnecessary for an animal in an aquatic environment?

Fish are wonderfully adapted to their environment. Their streamlined shape aids them in moving through the water. They also have a strong muscular tail and a broad tail fin to push them forward. The forward thrust is obtained by waving the tail from side to side. The single dorsal and anal fins keep fish stable as they move. (See figure 5.2.) The paired fins on either side of the body help them manoeuvre or pull up suddenly. The vertebral column is fairly light. It

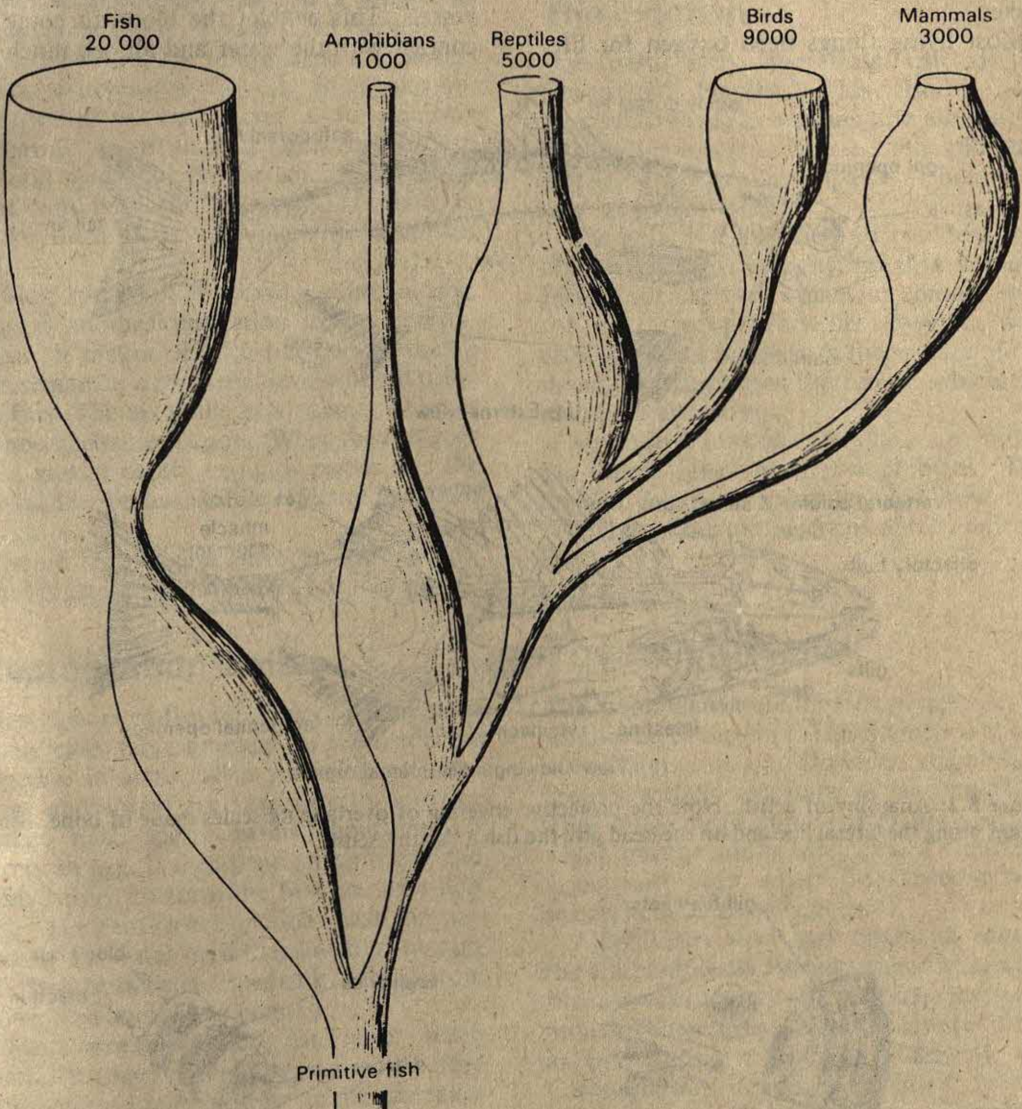
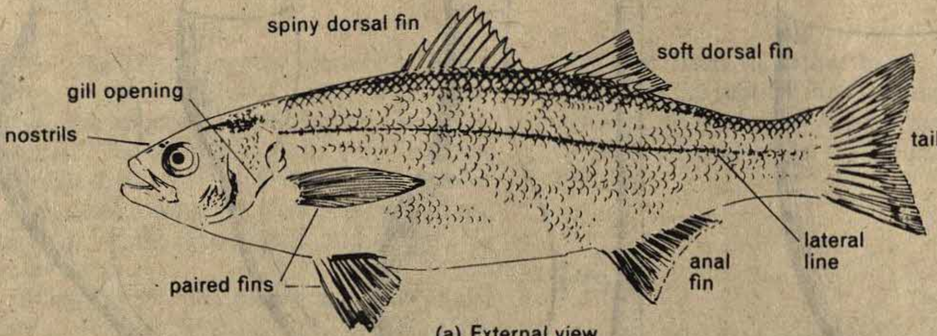


Figure 5.1: The evolutionary tree of the vertebrates. Most people believe that life began in a very simple form in the oceans. Over millions and millions of years, this simple form of life developed into more complex forms, among which were the fishes. The fishes were the first vertebrates. From the fishes evolved the amphibians and then the reptiles. The reptiles were the ancestors of the birds and the mammals.

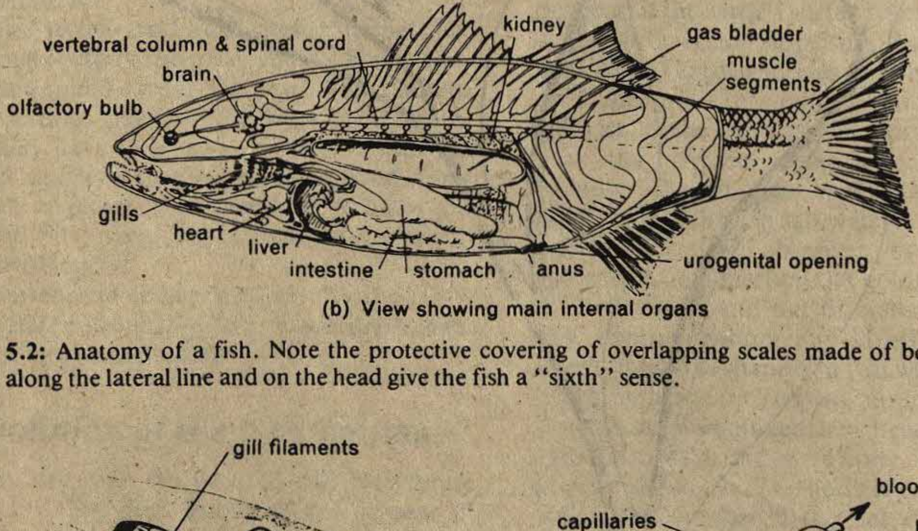
The diagram shows the approximate number of species in each group today. It also shows how these numbers varied in the past.

does not support the weight of the fish, which is buoyed up by the water. However, it holds the tissues together and carries the spinal cord. The vertebral column is fairly flexible to allow for the sideways movement of the tail and any sudden turn the fish may make.

Most living things need oxygen for life. We obtain our oxygen from the air we breathe in through our nose or mouth. Fish obtain their oxygen from the air that is dissolved in the water in which they live. This is done by allowing the water to flow over gills, which are rich in capillary blood vessels. This enables the blood to come in contact with the water and absorb much of

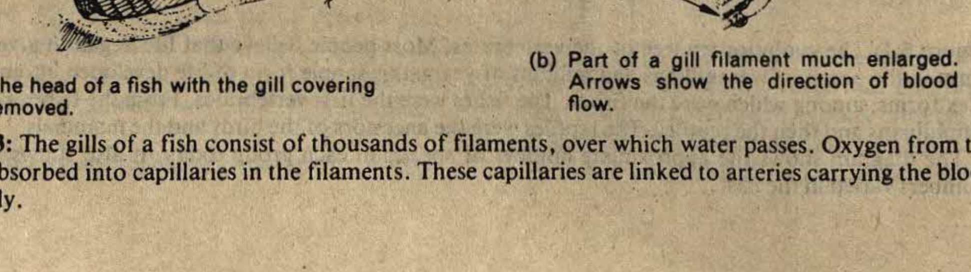


(a) External view



(b) View showing main internal organs

Figure 5.2: Anatomy of a fish. Note the protective covering of overlapping scales made of bone. Sense organs along the lateral line and on the head give the fish a "sixth" sense.



(a) The head of a fish with the gill covering removed.

(b) Part of a gill filament much enlarged. Arrows show the direction of blood flow.

Figure 5.3: The gills of a fish consist of thousands of filaments, over which water passes. Oxygen from the water is absorbed into capillaries in the filaments. These capillaries are linked to arteries carrying the blood to the body.

the oxygen dissolved in it. (See figure 5.3.)

A fish breathes by first closing the gills and allowing the mouth to fill with water. Then flaps close the mouth and the gill covers open outwards. At the same time the floor of the mouth rises. As a result, the water in the mouth is pushed out through the gills. See if you can follow these movements while watching a fish in an aquarium. Strange as it may seem, a fish quickly "drowns" in air. In air the gills collapse into a solid mass that the air cannot penetrate. The gills need the buoyancy of water to make them float and keep the filaments apart.

Most species of fish have a swim bladder. This is another adaptation to the environment. It makes the fish buoyant so that it can remain at a particular level without using its fins. The air tanks in a submarine serve almost the same purpose. When the fish goes to a greater depth, extra air passes into the air bladder because of the effect of increased pressure.

Some fish do not have an air bladder. They must move continuously or they sink.

Reproduction in fish

Most species of fish reproduce from eggs. In many cases large numbers of the fish come together in areas called spawning grounds. Eggs and sperm are shed directly into the water. Each sperm swims about until it meets an egg. It then penetrates the egg and joins with it to form the first cell of a new fish. The fertilized eggs float near the surface of the water until they hatch. (The eggs of many freshwater fishes sink to the bottom or become attached to plants.)

Most newly hatched fish never reach maturity; they are eaten by predators before they have a chance to grow up. Nature takes care of this situation by providing each female fish with a large number of eggs. The female cod, for example, sheds about five million eggs at a single spawning. It has been estimated that only four or five of these survive to reach maturity.

A number of fishes, including the sharks, give birth to live young. Fertilization therefore takes place internally. The male fish deposits sperm in special parts of the female's reproductive organs during mating.

The lungfish

One particularly interesting fish is the Queensland lungfish. This fish is well adapted to living in streams that almost dry up during drought. It has both gills and lungs and is therefore capable of breathing in air as well as water.

The lung is a modified air bladder. This bladder contains pockets, so that a much greater surface area comes in contact with the air. The pockets are covered with capillaries that are close to the surface of the tissue. This increases the rate at which the blood can absorb air.

A primitive lung like this one is not unlike the simple lungs of the amphibians. The lungfish helps us to understand how fish could have been the ancestors of the amphibians.

The amphibians

The amphibians were the first vertebrates to venture on to the land. This happened about 400 million years ago. However, amphibians are not entirely successful as land animals. They must spend part of their life cycle in water and the adults must have a moist environment. Even desert frogs need a wet season in order to reproduce.

Amphibians were very abundant during the Carboniferous Period, when the earth's surface was covered with luxuriant swamps. Some of these early amphibians were as big as present-day crocodiles. Following the Carboniferous Period, the earth's climate became drier and most species of amphibians became extinct. The only survivors today are the frogs, toads, newts and salamanders. Newts and salamanders are not found in Australia.

Experiment 5.1 describes how an aquarium may be changed into a suitable habitat for studying frogs. The frog is the commonest present-day amphibian. It has few body features of the fish. True, like a fish it has no neck or shoulders, but it has lost the tail and fins. The fins have been replaced by limbs. (See figure 5.4.)

A very significant difference between fish and frogs is the development of five "fingers" at the end of each of the frog's limbs. Over the millions of years since it first appeared, this development has evolved into the human hand.

Figure 5.4: The frog, a familiar amphibian, has strong rear legs and webbed feet. Because it cannot drink, it absorbs water through its skin. For this reason it must live near water to keep moist all the time.

Frogs have thin moist skins without scales or hair. Much of the breathing takes place through the skin, which is richly supplied with blood vessels. The eyes of a frog protrude above the head. Each eye has two eyelids. The upper one is thick and fixed; the lower one is thin and can move up and down. The eardrum is external and can be identified as an oval area of skin just behind the eye.

Reproduction in amphibians

Frogs reproduce in the same way as most fish. The female lays eggs in water and, at the same time, the male covers them with sperm-laden fluid. Each egg is covered with jelly, and eggs clump together to form a white frothy mass called frog spawn.

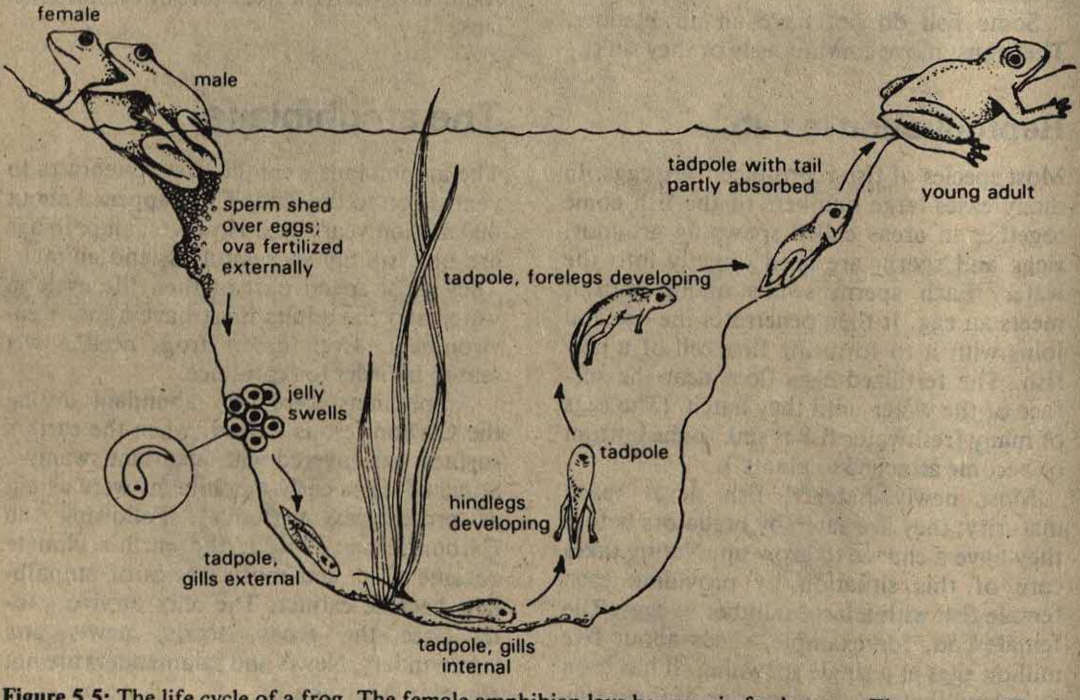

female
male
sperm shed over eggs; ova fertilized externally
jelly swells
tadpole, gills external
tadpole, gills internal
hindlegs developing
tadpole
tadpole, forelegs developing
tadpole with tail partly absorbed
young adult

Figure 5.5: The life cycle of a frog. The female amphibian lays her eggs in fresh water. These are fertilized by the male in the water. The young (tadpoles) are in the larval stage, and live in the water until they change into frogs. They then emerge from the water and become land animals.

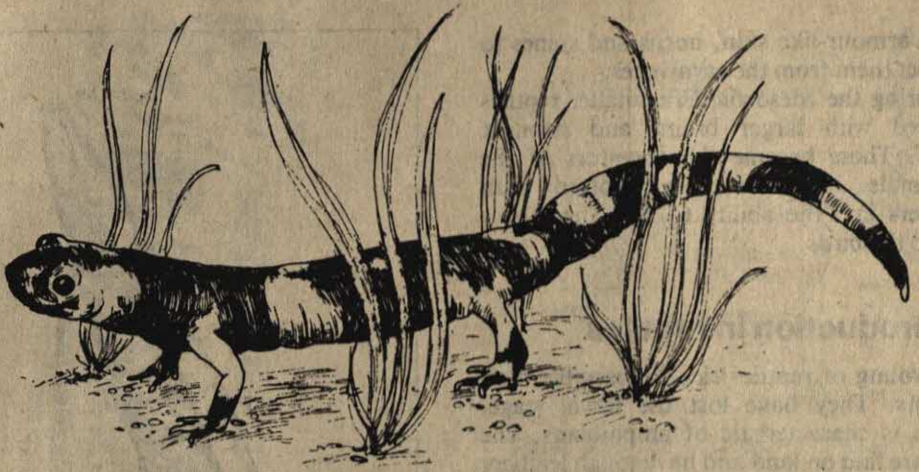


Figure 5.6: The salamander — an amphibian not as well adapted to life on the land as is the frog.

The larva that hatches from the egg is called a tadpole. A tadpole is not unlike a fish; it is aquatic and breathes through gills. Gradually its body widens and the mouth becomes larger. Hind legs appear and then front ones develop through the gill openings. By this time the tadpole has developed lungs and must come to the surface to breathe. These changes in the body are together called metamorphosis. During this stage the developing frog does not feed but absorbs the tissues of the tail for nourishment.

With the disappearance of the tail, metamorphosis is complete. The tadpole, which lived entirely in the water and breathed like a fish, has changed into a frog, which lives mainly on the land and breathes air into lungs.

Reptiles

The reptiles were the first true land vertebrates. There are about 5000 species alive today, including snakes, lizards, turtles and crocodiles.

Unlike their amphibian ancestors, reptiles have dry scales. This adaptation prevents loss of water through the skin, enabling them to lead completely terrestrial lives.

A snake, like the other reptiles, cannot cool itself by perspiring because its scaly skin has no sweat glands. In fact, its body temperature is the same as the temperature of its surroundings. To control its body temperature, a snake moves into the shade when too hot and into the sunshine when too cold. In winter its body temperature remains lower and it is therefore sluggish. In summer its body temperature is higher and it is very active. This means that its cells respire more rapidly and it must eat more food.

Snakes are limbless reptiles. They are carnivorous, with jaws and teeth adapted for capturing and killing their prey. Many snakes have hollow teeth linked to a poison sac. The poison is a special type of saliva. Some snakes have special jaws that enable them to swallow their prey whole. In South America there is one species that can swallow a whole calf.

The reptiles were most successful during the Mesozoic Era (sometimes called the "Age of Reptiles"), some 200 million years ago. No doubt you have seen drawings recreating many of these animals. Some, like the *Brontosaurus*, were so large that they could not exist out of water. They needed the water to support their huge weight — up to 100 tonnes. Some were carnivores and others herbivores. Many of the herbivores evolved thick armour-like skin, horns and spines to protect them from the carnivores.

During the Mesozoic Era smaller reptiles evolved with larger brains and stronger limbs. These became the ancestors of the mammals. Other reptiles evolved with feathers and the ability to fly. These gave rise to the birds.

Reproduction in reptiles

The young of reptiles closely resemble their parents. They have lost the larval stage, which is characteristic of amphibians. The eggs are laid on land and have tough leathery shells. They are fertilized inside the female before being laid. The young reptile fends for itself from the time it emerges from the egg.

Birds

There are few places on the earth's surface where birds have not been found. This is understandable, because there are over 8600 living species and most of these can fly. The wings of a bird are really lengthened arms. These wings are adapted for flight in a number of remarkable ways.

- Wings have special feathers attached to them. These provide the large area that the bird needs to push against the air when flying. Figure 5.7 shows the intricate design of a flight feather. It is both extremely light and very strong.
- Wings are streamlined to cut through the air and are curved to produce the lift that keeps the bird aloft.
- Wings have bones that are both extremely light and very strong. Figure 5.8 shows part of the wing bone of an eagle. Air spaces make the bone very light and flexible, while struts make it strong.
- Wings are powered by enormous muscles. These muscles are attached to a deep keel on the underside of the breastbone. (See figure 5.10.)

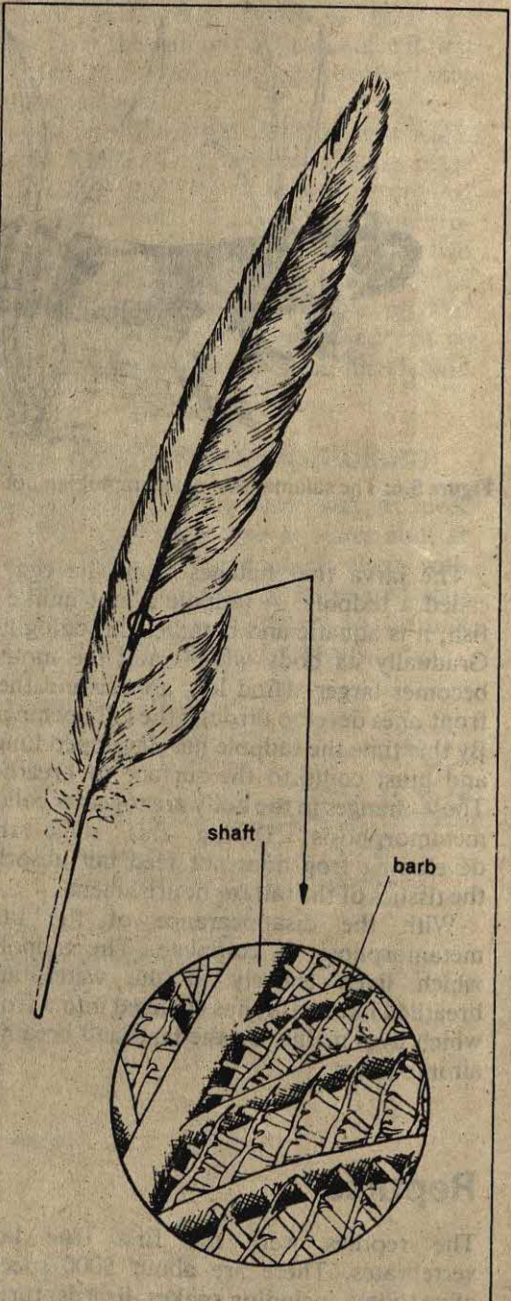


Figure 5.7: A bird's flight feather. It consists of a series of barbs attached to a central shaft. The space in between these barbs is filled with smaller barbs. These have hooks on them so that they interlock and form a mesh.

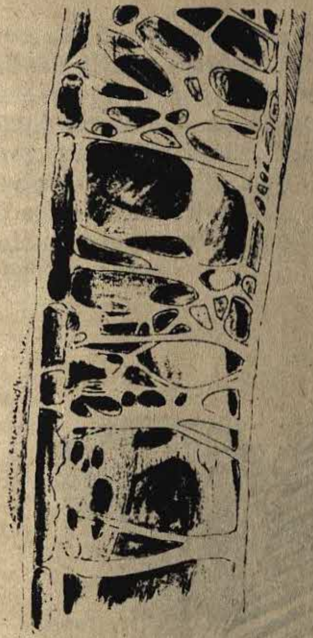


Figure 5.8: Part of the wing bone of an eagle. Air spaces make the bone very light. The struts give it strength.

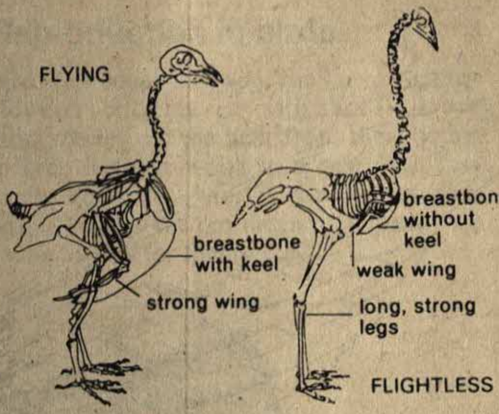


Figure 5.9: The skeletons of typical flying and flightless birds.

Some species of birds, such as the ostrich and the emu, cannot fly at all. They manage to escape their enemies in other ways. Usually they are very fast runners, possessing long, strong legs. Their wings, by comparison, are weak and almost useless. The deep keel of the breastbone, so prominent in flying birds, is absent. Figure 5.9 shows clearly the main differences between flying and flightless birds.

All birds, whether able to fly or not, have much in common. For example, they all have feathers, which are really modified scales. Most numerous are the contour feathers that coat the body, giving it a streamlined shape. These feathers are also very efficient at sealing in heat. The sparrow, for example, can keep a normal temperature of about 42°C when the outside temperature is well below freezing point. It can insulate itself by fluffing out its feathers, thus trapping more of the hot air warmed by its own body. Some species of birds, such as the mutton bird, are less thickly feathered. These migrate each year during winter to warmer parts of the world.

Birds use up a lot of energy, particularly in flight. Their body chemistry proceeds at such a rapid rate that they have enormous appetites in proportion to their size. If a normal man, for example, expended energy at the same rate as the tiny hummingbird, he would have to eat about 150 kilograms of food every day. Because birds have such big appetites only those varieties with successful adaptations for collecting food have survived.

Unlike reptiles, from which they evolved, birds are able to keep a constant body temperature. This probably came about because of their regular intake of food and the improved insulation of their bodies.

All species of birds are similar in body shape. For example, compare the eagle with the penguin. Although there is a marked difference between these species in wing size and the shape of the beak and feet, the difference is not nearly as great as between, say, the snake and the turtle, which are both reptiles.

The shape of the beak depends largely on the type of food that is eaten. The shape of the feet is related to the habitat in which the bird lives. Figure 5.11 shows a number of different beaks and feet. You can see how the special shapes help the birds survive in their different environments.

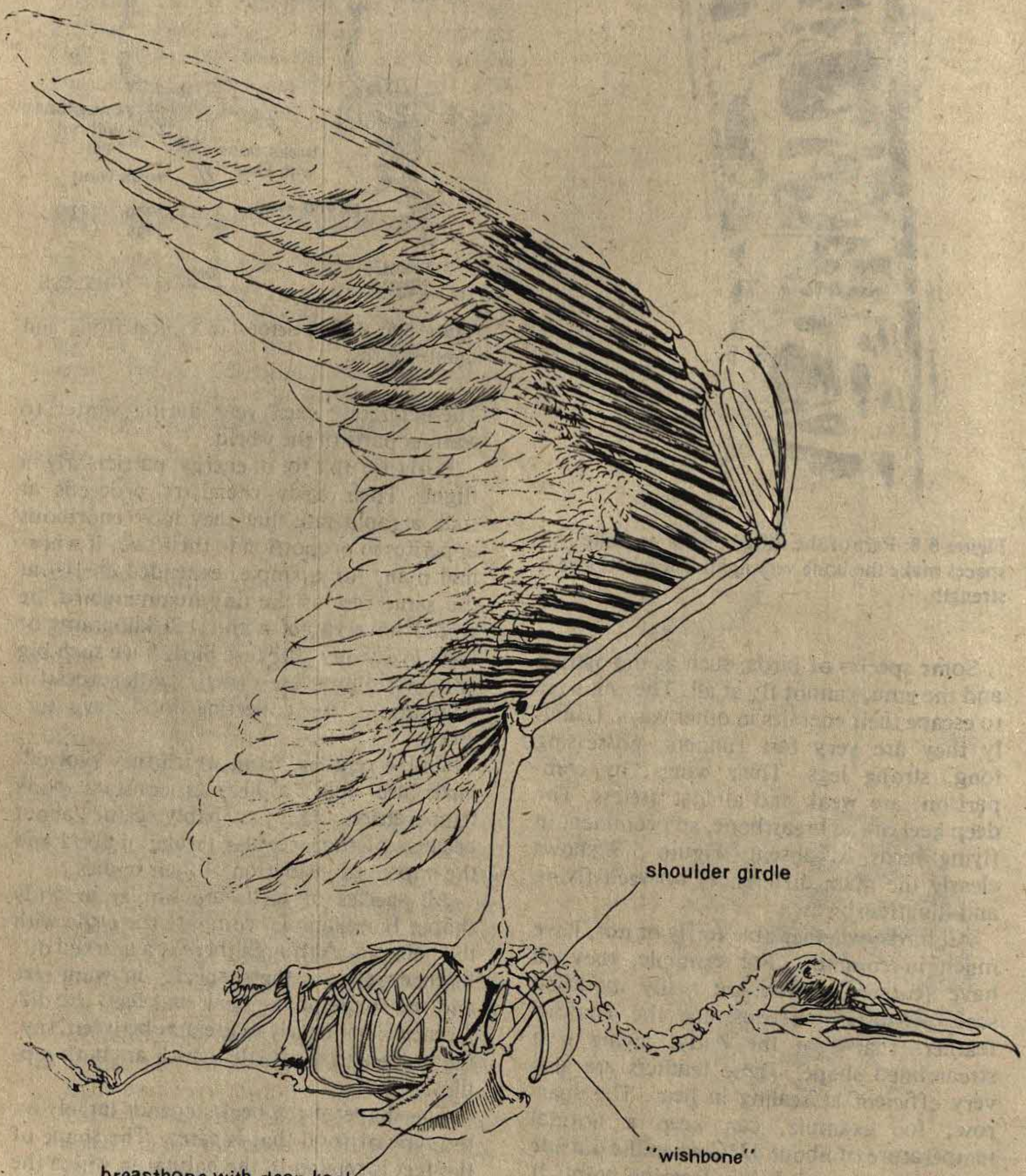


Figure 5.10: The skeleton of a gull suspended from its wing. Note the strong chest where the ribs lock on to the breastbone, which has a deep keel. Note also the shoulder girdle joined by the "wishbone".

The eyes of a bird are on either side of the head and this gives it a wide field of vision. Birds have very good sight, much better than ours. Think about how an eagle can spot small prey, such as a mouse, hundreds of metres below it. Birds also have very good hearing; again, it is better than ours. The opening leading to the eardrum is below and slightly behind the eye.

Reproduction in birds

Birds reproduce in a way similar to reptiles. However, birds lay eggs with hard shells and most species use the heat from their bodies to keep the eggs warm in a nest until they hatch. Birds also care for their young after birth — unlike the reptiles, which leave their young to fend for themselves.

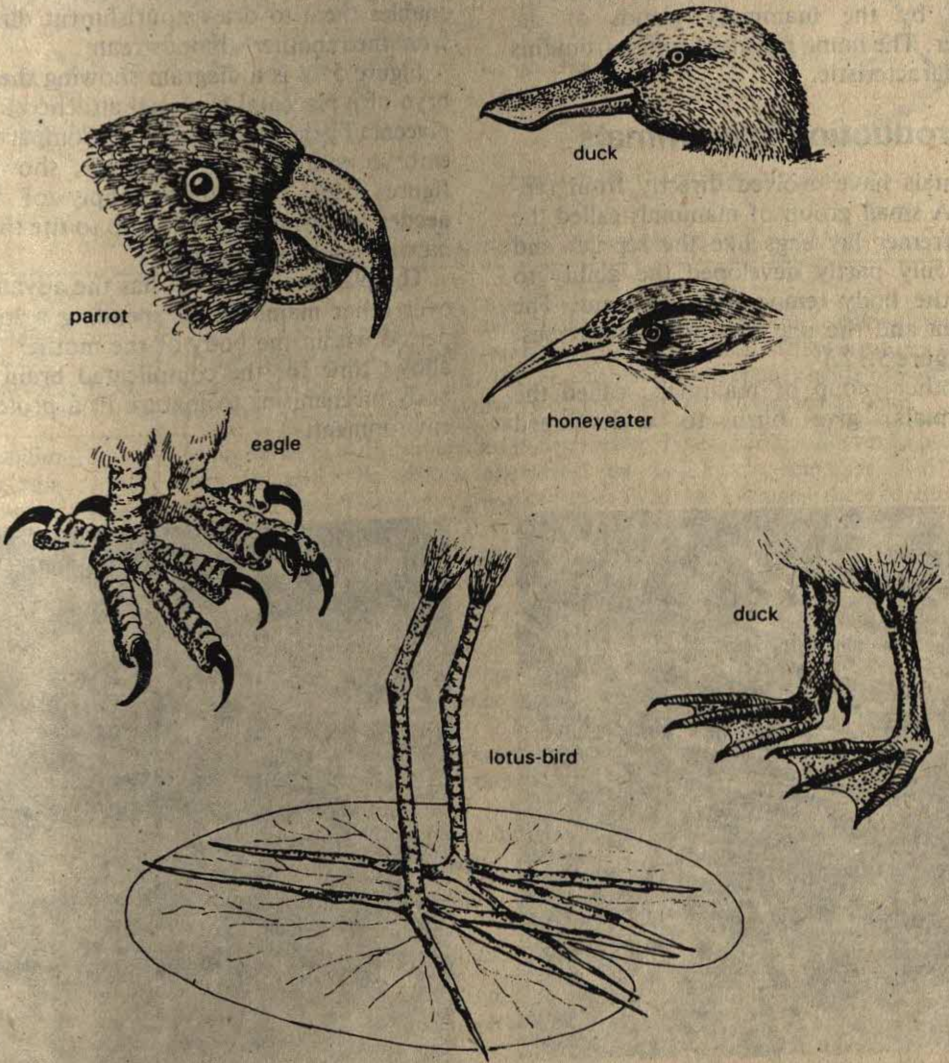


Figure 5.11: Some adaptations of beaks and feet of birds. The parrot feeds on hard seeds such as nuts. The duck sifts through mud for worms and grubs. The honeyeater sucks up nectar from flowers. The eagle's feet are adapted for perching in trees and picking up prey while flying. The lotus-bird walks on water-lily leaves. The duck's feet are adapted for swimming.

Mammals

Mammals are the most highly developed group of vertebrates. We belong to this group. Mammals are warm-blooded animals with bodies more or less covered by hair. (Some mammals, such as the whale and the dolphin, have a thick layer of fatty blubber instead of hair to conserve the heat of the body.) Young mammals are fed on milk produced by the mammary glands of the mother. The name *mammal* comes from this last characteristic.

Reproduction in mammals

Mammals have evolved directly from reptiles. A small group of mammals called the monotremes lay eggs like the reptiles and have only partly developed the ability to keep the body temperature constant. The echidna and the platypus are monotremes. (See figure 5.12.)

Another group of mammals, called the marsupials, give birth to undeveloped young. These young complete their development attached to a teat in the mother's pouch.

The largest group, the placental mammals, also give birth to live young. However, the young of placental mammals are more developed at birth than are the young of the marsupials. They are sustained during development in their mother's womb through a collection of tissues called the placenta. This enables them to draw nourishment directly from their mother's bloodstream.

Figure 5.14 is a diagram showing the embryo of a placental mammal attached to the placenta by the umbilical cord. Compare this embryo with that of the chick, shown in figure 5.15. The entire supply of food needed to sustain the chick up to the time it hatches is inside the egg.

The placental mammal has the advantage over other mammals of spending a longer period within the body of the mother. This allows time for the complicated brain and body mechanisms to mature in a protected environment.

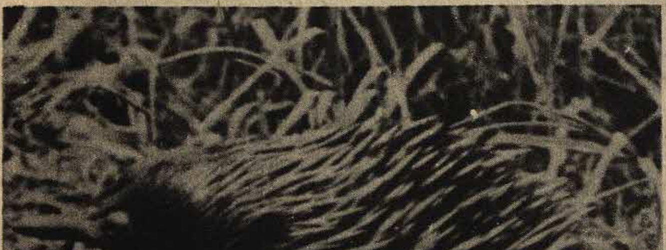


Figure 5.12: The echidna. This is a monotreme with a special tube-like snout and a long sticky tongue, well adapted for scooping up ants, its favourite food.

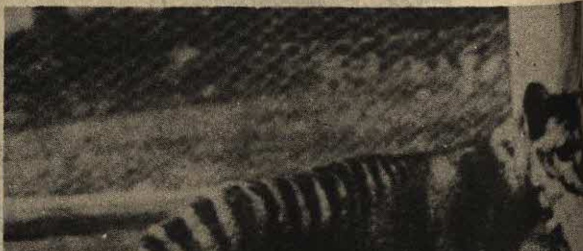
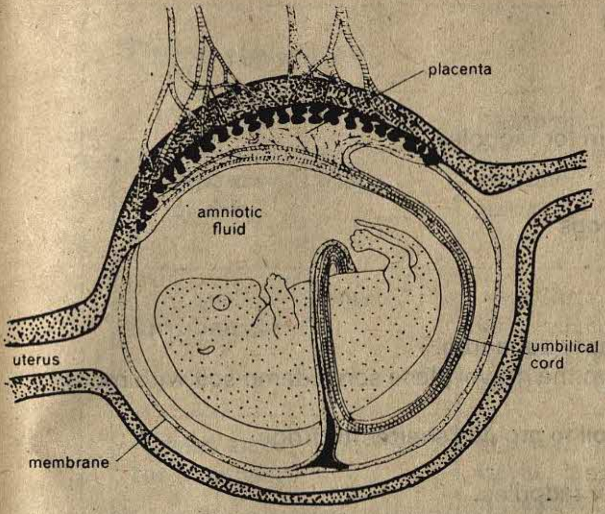


Figure 5.13: One of the last of the Tasmanian tigers (thylacines), in the Hobart zoo, about 1930. This marsupial was wiped out by uncontrolled shooting. (Photo courtesy Tasmanian Museum)



◄ **Figure 5.14:** The embryo of a placental mammal attached to the placenta by the umbilical cord.

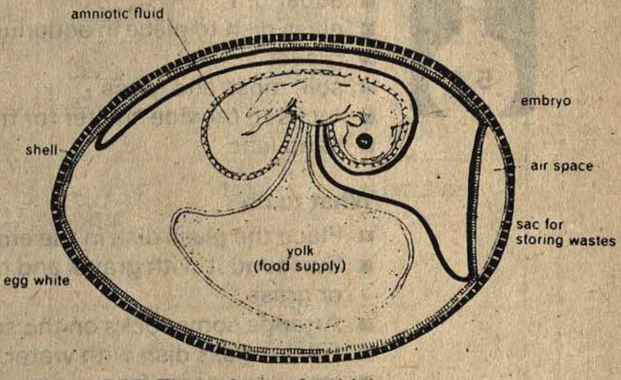


Figure 5.15: The embryo of a chick.

Table 5.1: The development of the vertebrates

Time	Events
500 million years ago (Palaeozoic Era)	The first fish appeared. It is thought they evolved from a mud-sucking creature that wriggled like a tadpole over the bottom of the ocean. These creatures had a spinal cord but no backbone. The first fish had a backbone, made of cartilage, but no jaws. Later, species evolved with jaws and vertebrae made of bone.
400 million years ago (Palaeozoic Era)	Many varieties of fish flourished in deep water. Later, parts of the world became very dry and some shallow lakes dried up. As a result, some species of fish became extinct. However, a group of fish evolved that overcame these conditions. They had primitive lungs that were modified gas bladders and strong fins strengthened by bones that became part of the skeleton. They were able to move on these fins across dry land to deeper pools and were also able to breathe air through their lungs. They were the first step in the evolution of amphibians.
340 million years ago (Palaeozoic Era)	The first reptiles began to appear. They were the first vertebrates to be completely free of the sea. Unlike the amphibians, they had no aquatic larval stage, their young taking up a land existence as soon as they were hatched. As well, the adults did not need to return to water in order to breed. The evolution of reptiles was a major event in the history of life on earth. Reptiles flourished during the Jurassic Period of the Mesozoic Era, some 150 million years ago. Some of the largest animals that have ever existed were Mesozoic reptiles. These giant species became extinct at the end of the Mesozoic Era, about 60 million years ago.
140 million years ago (Mesozoic Era)	Warm-blooded animals evolved from reptiles. These were primitive mammals. They bore live young. Unlike the reptiles, the mammals fed their young by suckling them through special glands.
130 million years ago (Mesozoic Era)	The first true birds evolved from reptiles. They had forelimbs modified for flight and were, like the mammals, warm-blooded.
3 million years ago (Cainozoic Era)	First human-like creatures appeared.

EXPERIMENT 5.1

Tracing the life cycle of the frog

Each group will need:

- aquarium
- glass dish to place in aquarium for tadpoles
- gravel
- soil, moss and grass
- rocks to provide shelter for frogs
- hand lens

What to do

- Place the glass dish in the empty aquarium.
- Surround it with gravel and on the gravel place some damp soil with moss or grass.
- Arrange some rocks on the soil to provide shelter for frogs.
- Fill the glass dish with water.
- Introduce some frog spawn or tadpoles.
- Follow the life cycle through to the adult stage. Tadpoles can be fed on boiled lettuce leaves, frogs on worms and flies.
- Examine a tadpole with a hand lens, looking for the eyes, mouth and gills. Note how these features change during metamorphosis.
- Examine the mature frog carefully. Note the mouth structure, eyes, eyelids and eardrums. Look for the five fingers on each limb.

EXPERIMENT 5.2

Examination of a bird's skeleton

Each group will need:

- wing bones, breast bone, leg bones and feet of a chicken

What to do

- Examine the wing bones and try to work out which parts correspond to the five fingers of a land mammal.
- Examine the breast bone, identifying the large keel bone. The muscles attached to this bone work the wings and are the largest in the bird's body, despite the fact that domestic chickens fly very little.
- Look at the leg bone. Notice the scales on the lower part of the leg. These change to feathers on the upper part of the limb.

Spelling list

amphibian
ancestor
aquatic
buoyant
capillary
Carboniferous
carnivorous
evolve
fertilize
gill
keel
larva
larvae
mammal
mammary
Mesozoic
metamorphosis
muscle
Palaeozoic
placenta
scaly
spawn
terrestrial
vertebrate

The vertebrates

<table>
<tr><th></th><th>Fish</th><th>Amphibians</th><th>Reptiles</th><th>Birds</th><th>Mammals</th></tr>
<tr><th>Appearance of skin</th><td>scaly</td><td>wet and naked</td><td>dry and scaly</td><td>covered with feathers</td><td>covered with hair or fur</td></tr>
<tr><th>Usual environment</th><td>water</td><td>water for larvae, land or water for adults</td><td>land or water</td><td>land</td><td>land or water</td></tr>
<tr><th>Organ used for breathing</th><td>gills</td><td>gills for larvae, lungs for adults</td><td colspan="3">lungs</td></tr>
<tr><th rowspan="2">Usual method of reproduction</th><td colspan="2">females lay fragile eggs with no shells</td><td>females lay soft-shelled eggs</td><td>females lay hard-shelled eggs</td><td>females bear live young</td></tr>
<tr><td colspan="2">eggs are fertilized in water after laying</td><td colspan="3">eggs are fertilized inside females</td></tr>
<tr><th>Care of young</th><td colspan="3">young find their own food</td><td>young are fed until they can fly</td><td>young are suckled</td></tr>
<tr><th>Adaptations for movement</th><td>fins for swimming</td><td colspan="4">limbs evolved from fins
forelimbs of birds modified for flight</td></tr>
<tr><th>Blood temperature</th><td colspan="3">depends on temperature of environment</td><td colspan="2">constant, does not depend on temperature of environment</td></tr>
</table>

Things to do

5.1 Visit a zoo or a museum. Study one group of vertebrates only. For example, suppose you choose reptiles. Notice

- any modifications to the scaly skin (compare the turtle and the snake)
- any limbs adapted for running, climbing or swimming
- the shape of the body
- the structure of the mouth and teeth.

5.2 Visit an aquarium. Note particular features of different fish. For example,

- the shape of the flathead, garfish and boxfish
- the movement of the gills during breathing
- the use of the fins during movement
- the colours of the fish — on top and underneath.

Note any unusual specimens such as the angler fish, the decoy fish or the lungfish.

5.3 Find out about Antarctic penguins. How do they survive the Antarctic winter? How do they hatch their eggs? What are their wings used for?

5.4 Whenever you visit the seashore or coastal lagoons, be on the lookout for birds. Identify any birds you see. Note how the bird feeds and what special adaptations it has to help it get its food.

More questions

5.5 Why is the vertebral column of fish fairly light?

5.6 Explain the function of a fish's gas bladder.

5.7 The eyes of a fish are generally placed on the sides of the head. How does this affect the vision of the fish?

5.8 Seals can live equally well in water and on land. Why are they not classed as amphibians?

5.9 What adaptation allows a frog to be a strong swimmer?

5.10 What adaptations of the adult amphibian were most helpful for the later evolution of reptiles, birds and mammals?

5.11 Name three flightless birds. Name the country in which each is found. How do the skeletons of these birds differ from the skeletons of strong fliers? (R)

5.12 Why do birds have such big appetites?

5.13 List three ways in which the wings of a bird are adapted for flight.

5.14 How is the name *mammal* derived? (R)

5.15 What is the function of the umbilical cord in placental mammals?

5.16 In what respects do the monotremes still resemble reptiles?

5.17 How many groups of mammals are there? Name several members of each of these groups.

5.18 Explain how fish can detect danger without actually seeing it.

5.19 How do sharks differ from bony fish? (R)

5.20 How is the lungfish adapted to survive in streams that dry up?

5.21 What enables the mudskipper to remain out of water for prolonged periods?

5.22 The liquids in the body of a freshwater fish are saltier than the surrounding water. The reverse is true for a saltwater fish. Explain how fish might be affected by this. (R)

5.23 Of fresh and saltwater fish,
(a) which drinks more?
(b) which passes more urine?
Explain your answers. (R)

5.24 Explain why frogs possess a stronger skeleton than fish of the same weight.

5.25 The filaments in the gills of a fish are supported and separated by the water that passes over them. Use this fact to explain why fish are unable to breathe when out of water. (R)

5.26 Each of the three straight lines drawn in the graph in figure 5.16 shows how the body temperature of an animal is affected by change in the temperature

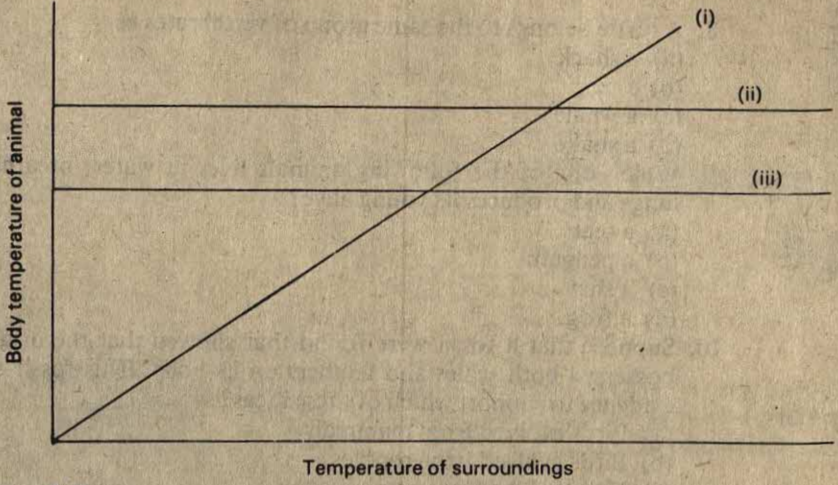


Figure 5.16

of its surroundings. Which is the line for a reptile, which for a mammal and which for a bird?

5.27 What are feathers? Are they alive? Name two types of feathers and briefly outline the use of each. Why do birds lose their feathers at least once a year?

5.28 What prompts certain species of birds to migrate each year? (R)

5.29 What is the function of the amniotic fluid shown in figures 5.14 and 5.15?

5.30 Have you ever noticed something about the legs of birds that supports the idea that birds may have developed from reptiles? What?

Test yourself (chapter 5)

Write the answers to questions 1 to 6 in your workbook.

1. What is the name of the group of vertebrate animals that includes turtles, alligators and dinosaurs?
2. What class of vertebrate animals was the first to be capable of reproduction on dry land?
3. The echidna suckles its young like any other mammal. Yet it is placed in a different group from most other mammals. Why?
4. The dragonfly lays eggs in water. The eggs hatch out into larvae that eventually change into adult dragonflies. Why then is the dragonfly not classed as an amphibian?
5. What organ had to evolve to enable vertebrates to adapt to life out of water?
6. What are the differences between amphibians and reptiles that enable reptiles to live away from water?

Choose the best answer to each of the questions 7 to 11 and write its letter in your workbook.

7. Of the following, the two animals most closely related are
   (a) bat and fly
   (b) snake and worm
   (c) whale and horse
   (d) emu and kangaroo.

8. A turtle belongs to the same group of vertebrates as
   (a) a shark
   (b) a frog
   (c) a whale
   (d) a snake.
9. Which one of the following animals lives in water, breathes by means of lungs and produces its young alive?
   (a) a seal
   (b) a penguin
   (c) a shark
   (d) a frog.
10. Suppose that a fossil were found that showed that the original animal had possessed both scales and feathers on its body. This fossil could be used as evidence to support which of these ideas?
   (a) Birds evolved from mammals.
   (b) Birds evolved from reptiles.
   (c) Fish evolved from amphibians.
   (d) Amphibians evolved from reptiles.
11. Figure 5.17 consists of drawings of four vertebrate animals. A possible order of evolution among these animals is
   (a) P → Q → S
   (b) Q → P → S
   (c) Q → R → P
   (d) R → S → P.

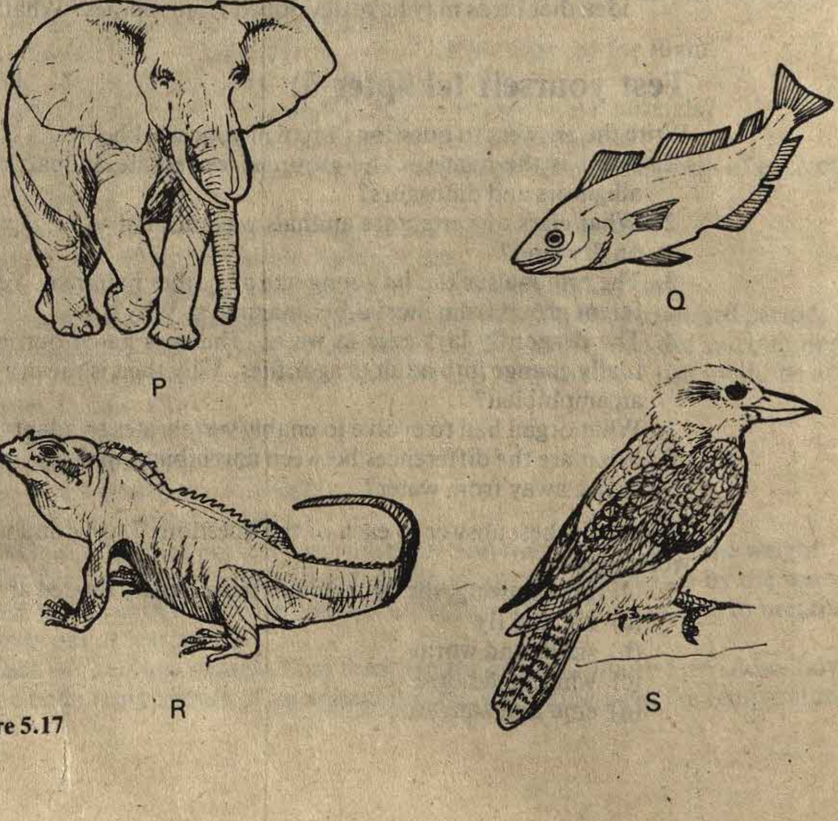


Figure 5.17

6

Refraction of light

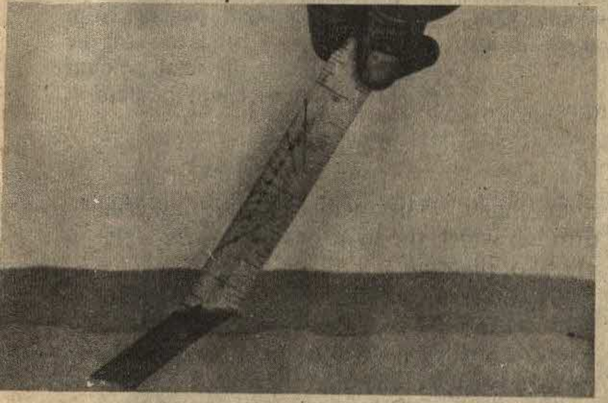


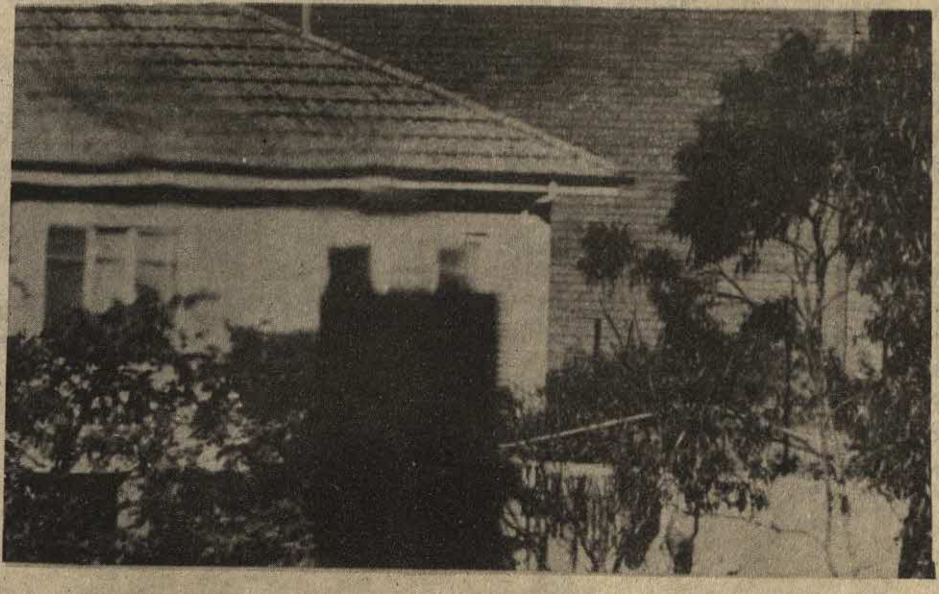
Figure 6.1: Photograph showing how a ruler appears bent when partly submerged in water.

Most of us have noticed how objects that are partly submerged in water appear bent at the water's surface. An example of this is shown in figure 6.1.

No doubt you have also seen the effect photographed in figure 6.2. The gutter line of the house appears bent where you see it through an area of hotter air.

These two phenomena are caused by the bending of the light rays coming from an object to our eyes. The rays are bent coming from water into air in figure 6.1 and as they come through hot air in figure 6.2. In this chapter we are going to try to find out why light rays bend as they pass from one transparent substance to another.

Figure 6.2: The shimmering effect caused by looking at things through rising hot air. Hot air is coming out of the dark chimney in the foreground. Notice how the gutter line appears bent. This is happening because rays of light are bent by different amounts as they come through the rising hot air towards the camera.



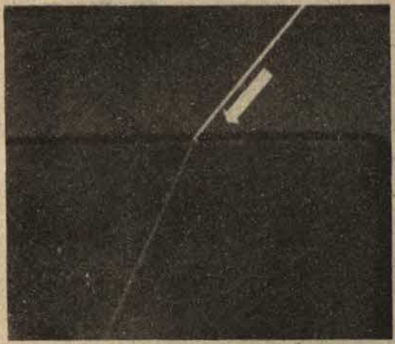


Figure 6.3: Light passing from air to glass — it bends away from the surface. Notice the small amount of reflection off the surface of the glass.

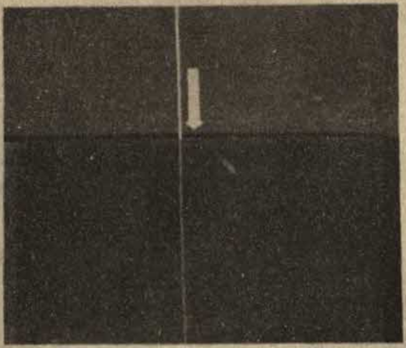


Figure 6.4: Light striking the glass at right angles — there is no refraction.

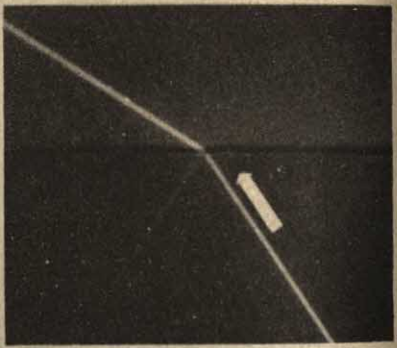


Figure 6.5: Light passing from glass to air — it bends towards the surface. Notice the small amount of reflection back into the glass.

Investigating refraction

Figure 6.3 is a photograph showing what happens when a ray of light from a ray box passes from air into glass. Notice how the ray is bent (refracted) as it enters the glass. Notice also that the bending is *away* from the surface of the glass. In figure 6.4 the ray strikes the glass at right angles; we call this striking the glass normally. In this case the ray goes straight on — there is no bending.

The situation is reversed in figure 6.5. Here the light is passing from glass into air. Notice how the ray now bends *towards* the surface of the glass as it comes out into the air.

These experiments can be repeated using water in an aquarium. In order to see the ray in air, we blow smoke across the surface of the water. So that we can see the ray in the water, we add a little red ink to the aquarium.

As a result of all these experiments we can say:

- When light enters a denser medium it bends away from the surface between the two media.
- When light enters a less dense medium it bends towards the surface between the two media.

Remember, however, that in both cases there is no bending if the ray strikes the surface at right angles. (The medium is the material through which the light passes; *media* is the plural of *medium*.)

We can now explain why the ruler appears bent at the surface of the water. It is because rays from the ruler will be bent towards the surface as they come out into the air on their way to the eye. (Refer to figure 6.6.) The eye follows the rays straight back to the point that they *appear* to come from. This creates the illusion that the ruler is above its true position. The image of the ruler in the water is therefore a virtual one.

So far we have only given examples of the bending of light. We have not attempted to explain the bending. This we shall now do.

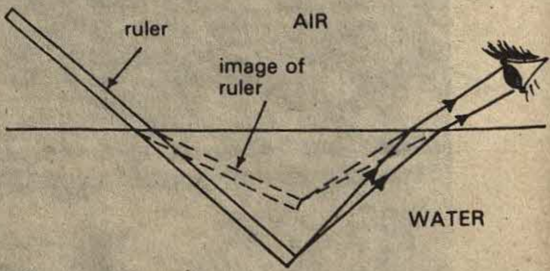


Figure 6.6: Why the ruler appears bent. Rays of light coming from the ruler are bent when they leave the water. To the eye they therefore appear to come from a point higher in the water. The ruler therefore appears to be bent upwards.

Searching for an explanation of refraction

Do you ride a bicycle? If you do, you may have had the experience of going from a smooth hard surface into sand or mud. When you do this the front wheel is slowed down and the handlebars tend to turn to the right or left. This may even throw you off.

The way a bicycle behaves when travelling from hard to soft ground offers a clue to why a beam of light changes direction when it passes from air into glass. Could it be that the light beam is slewed around because its speed is reduced in the glass?

A study of water waves supports this idea. Figure 6.7 is an aerial photograph of the entrance to Broken Bay, on the coast of New South Wales. Notice what happens when waves rolling into the bay come to the sandbank on the right. The shallow water slows them down. The result is a distinct change in the direction the waves are travelling. Figure 6.8 may make the explanation clearer.

Next time you visit a surf beach, watch the waves as they come into shallow water. If they strike a sandbank obliquely, you may see the same effect as in figure 6.8.

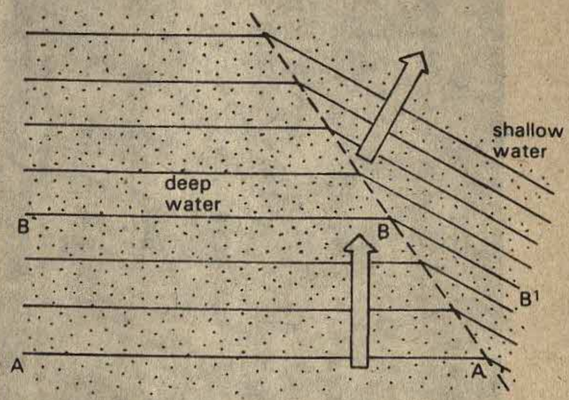


Figure 6.8: By the time wave AA has reached position BB, the right-hand side of it has entered the shallow water and slowed down. This has the effect of changing its direction, even though the wave in the deep water goes straight on.

Many schools have a ripple tank for studying water waves. Figures 6.9 and 6.10 are two photos of waves generated in a ripple tank. Figure 6.9 shows that the wavelength is shortened when the waves pass from deep into shallow water. This is understandable because, as the waves are slowed down, the crests are pulled closer together. Figure 6.10 reinforces the argument that it is the slowing down of the waves that causes them to change direction.

Would you agree that we have found a satisfactory explanation of the refraction of light rays — that it is caused by the change of speed that takes place when light travels from one material into another?

Figure 6.7: An aerial photograph of the entrance to Broken Bay on the coast of New South Wales. Notice how the waves rolling in from the ocean are slowed down as they come to the sandbank on the right. This slowing down causes a change in the direction the waves are travelling. (Photo courtesy New South Wales Department of Lands)

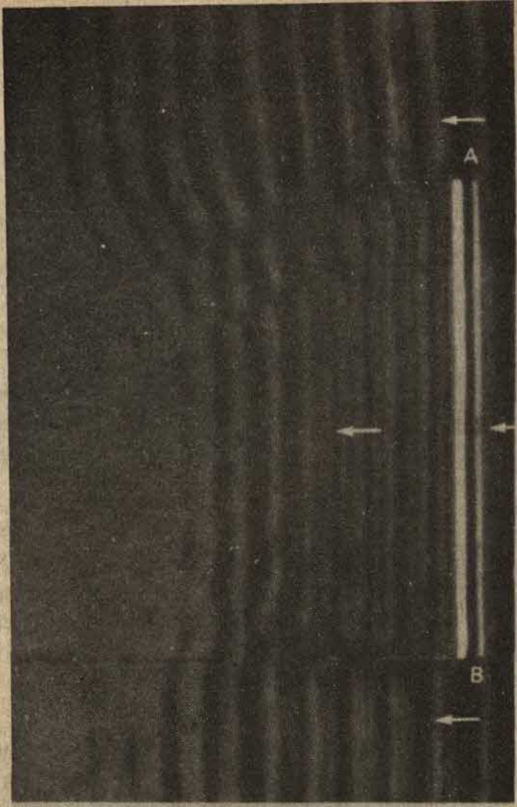


Figure 6.9: Waves passing into a shallow region without change in direction. The shallow region is to the left of the line AB. Notice that the wavelength is shorter in the shallow region.

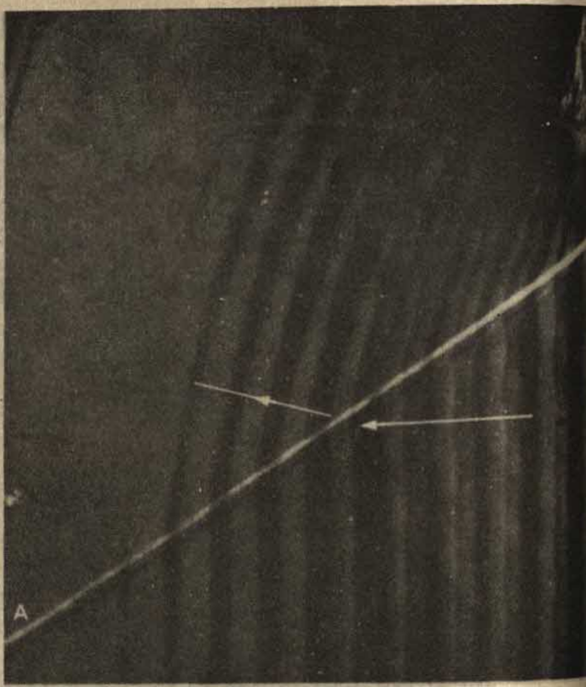


Figure 6.10: Waves bending away from the edge AB as they pass into the shallow region.

Some phenomena caused by refraction

The sparkle of diamonds. Diamonds refract light more than any other material. Diamonds used in jewellery are carefully cut to shapes that make full use of this property. Light entering the top of the diamond is bent so much that it is reflected by the underneath surface of the gem and comes out again through the top. This causes the sparkle. With a piece of glass the same shape, much of the light entering the top would pass out the bottom.

Focusing of light by lenses. A lens may be used as a burning glass to set fire to a piece of paper. This can be done because the heat rays from the sun, as well as the light rays, are bent on passing through the lens so that they all travel towards a single point called the focus. At the focus both the heat and light are concentrated.

Mirages. Mirages may be seen on hot days on bitumen roads or on flat sandy areas. The hot air in contact with the road acts like a mirror. (See figure 6.11.) Hot air is less dense than cool air. Light travels faster in less dense air. Therefore, rays of light coming from cool to hot air are bent towards the junction of the two layers. This happens at each successive layer of hotter air until the ray is eventually turned so much that it is reflected upwards. The eye, following this emerging ray backwards, imagines it is coming from a point below the road's surface. (See figure 6.12.)

Displacement of stars. Rays of light coming from a star are bent as they pass into the earth's atmosphere. (See figure 6.13.) This creates the illusion that the star is higher in the sky than it really is. Note, however, that this phenomenon does not occur if the star is directly overhead. Why?

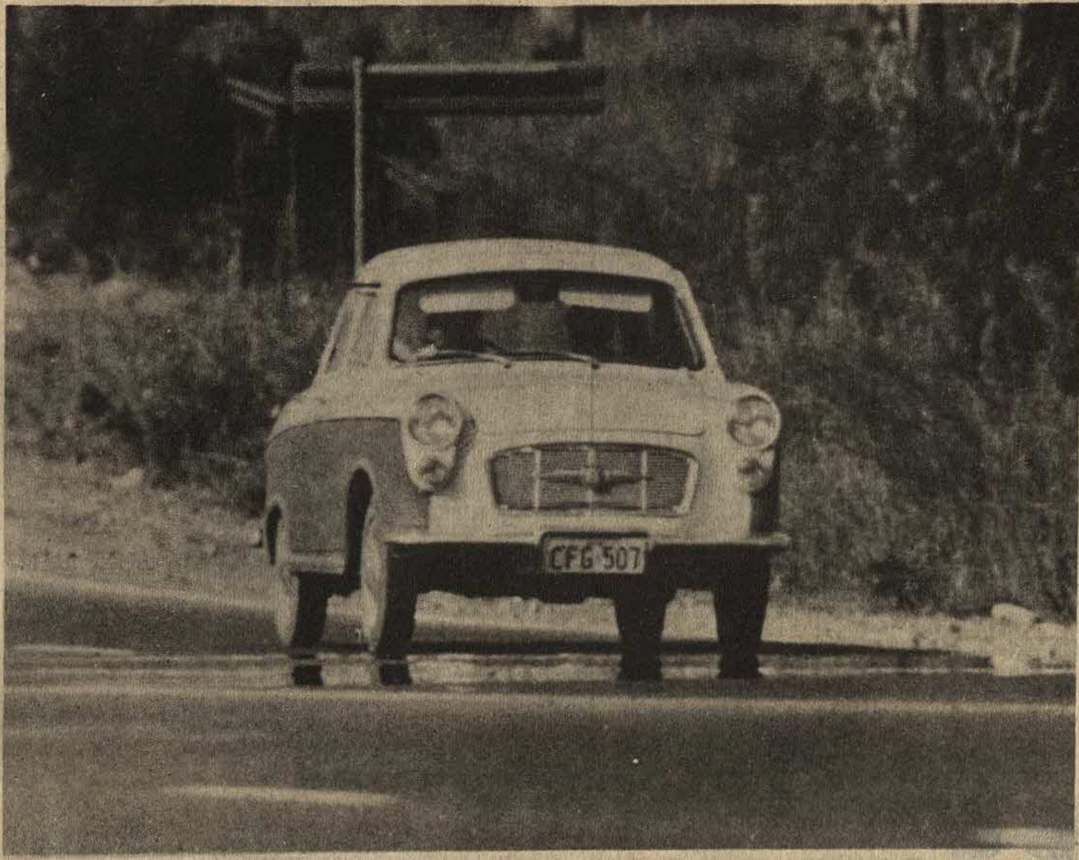


Figure 6.11: A mirage on a hot, dry, bitumen road. Notice the images of the tyres. This gives the appearance of water lying on the road. Notice also the image of the small white object on the right.

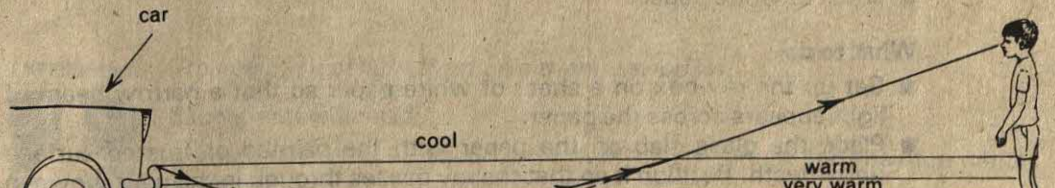


Figure 6.12: The air close to the road is hotter than the air above. Rays of light travel faster through the hotter air and are bent as shown in the diagram.

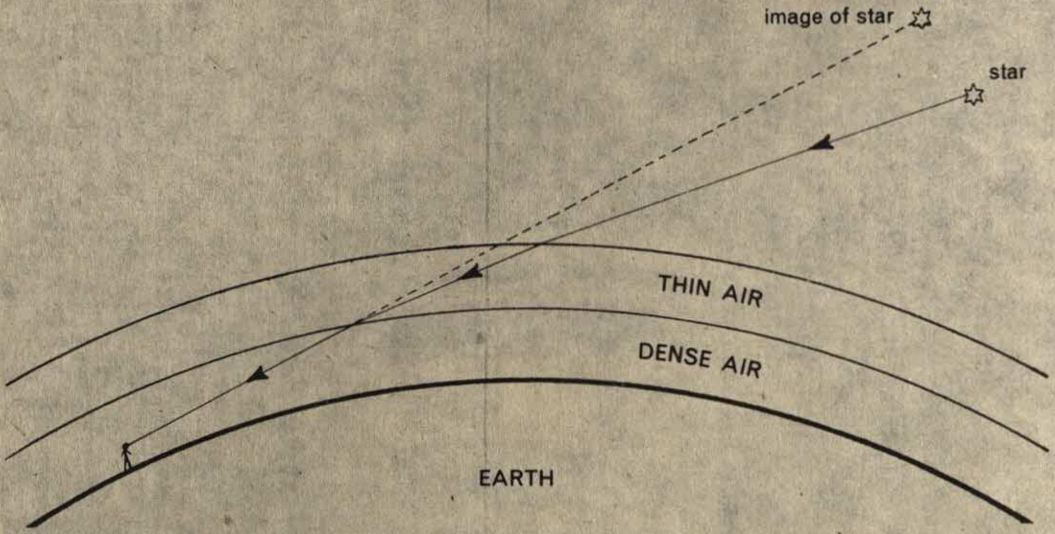


Figure 6.13: Stars appear higher in the sky than they really are because of refraction by the earth's atmosphere.

EXPERIMENT 6.1

Tracing a ray of light through a rectangular glass slab

Each group will need:

- ray box
- power pack
- glass slab with parallel sides and with one face frosted or coated with quick-drying paint
- sheet of white paper

What to do

- Set up the ray box on a sheet of white paper so that a narrow beam of light appears across the paper.
- Place the glass slab on the paper with the painted or frosted surface underneath. Position it so that the ray passes through in the way shown in figure 6.14.
- Trace the outline of the slab on the paper. Mark also the directions of the incident ray, the emergent ray and any reflected ray.
- Move the slab away and, with a ruler, join the point where the ray enters the slab and the point where it comes out of the slab.
- Repeat the procedure twice, using a different angle of incidence each time.

Questions

6.1 Did you notice anything about the incident and emergent rays?

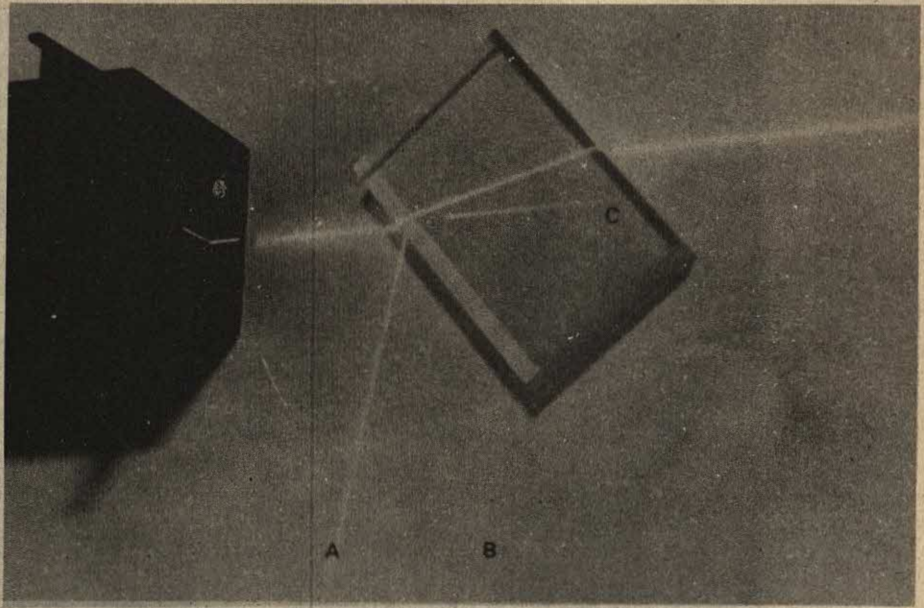


Figure 6.14: Using a ray box to trace the path of a ray of light through a glass slab with parallel sides. Note the reflected rays, A and B, and the direct ray, C, that comes out of the box above the slab.

6.2 Did you notice that the ray had been pushed sideways (displaced) as it passed through the slab? Does this sideways displacement remain the same for different angles of incidence? If not, what is the relationship between the displacement and the angle of incidence?

6.3 Was there any evidence of reflection at any of the faces of the slab? If so, which ones? When did you get the greatest reflection?

EXPERIMENT 6.2

Tracing a ray of light through a triangular prism

Each group will need:

- triangular glass or plastic prism with one triangular face painted white
- power pack
- ray box
- sheet of white paper

What to do

- Set up the equipment as described in experiment 6.1. (Refer to figure 6.15 on page 82.)
- To draw the path of the ray through the prism, first trace the incident and emergent rays, then lift the prism off the paper and join the points of entry and emergence of the ray.
- Repeat the procedure using different angles of incidence.

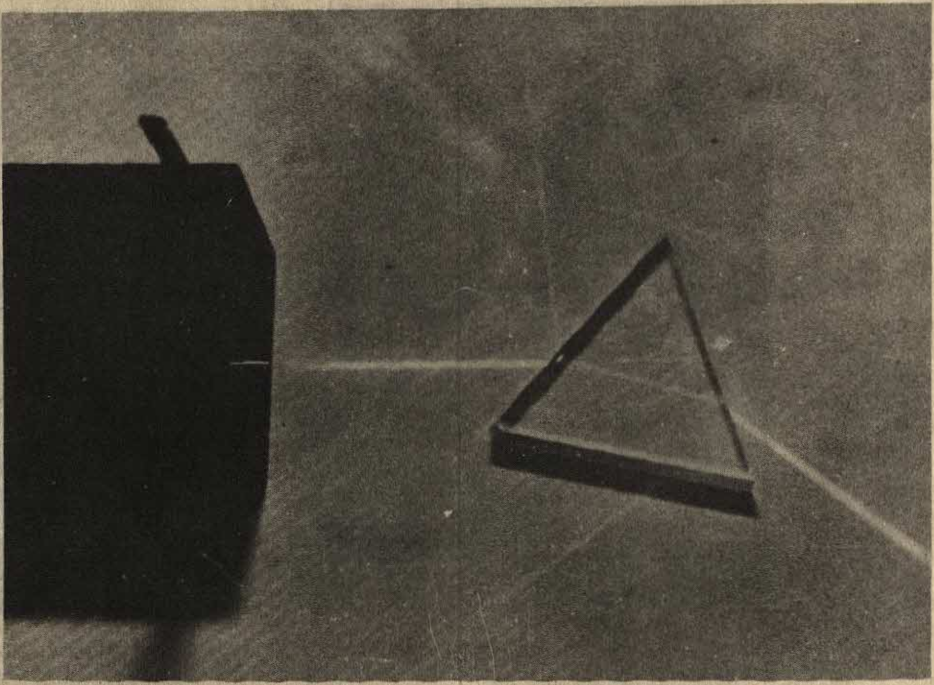


Figure 6.15: Tracing the path of a ray of light through a triangular prism. Note the two faint reflected rays.

Questions

6.4 Do you remember that, with the glass slab in experiment 6.1, the emergent ray was parallel to the incident ray? In this experiment was the emergent ray also parallel to the incident ray?

6.5 Describe any reflection you saw at any of the glass faces of the prism.

6.6 Did you notice any colour in the rays emerging from the prism? If so, describe it.

Refraction of light

- Light travels at different speeds in different transparent materials: the denser the material the slower the speed.
- Light entering a denser material obliquely is bent away from the surface.
- Light entering a lighter material obliquely is bent towards the surface.
- There is no refraction if the light strikes the surface between two materials at right angles.
- It appears that refraction is caused by a change in speed as light passes from one material to another.

Spelling list

emergent	parallel
incident	phenomena
mirage	refraction
oblique	transparent

Things to do

6.7 Place a lighted candle in front of a *thick* glass mirror. How many images can you see? (Refer to figure 6.16.) Explain how these images occur.

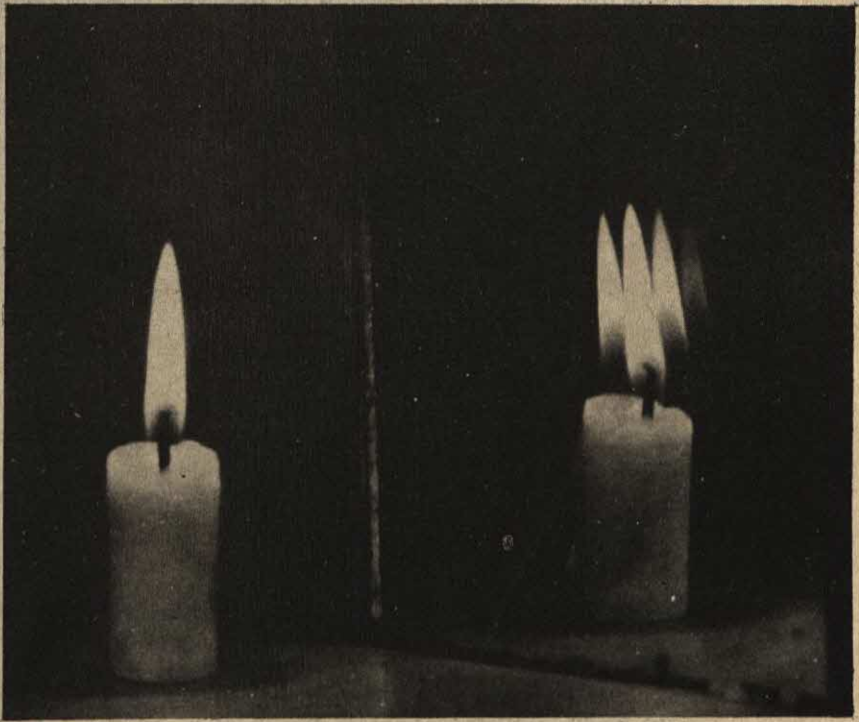


Figure 6.16

6.8 Place a coin on the bottom of a saucepan with vertical sides. Look down into the saucepan at such an angle that the coin is just out of sight, hidden by the rim of the saucepan. Without moving your head, have someone pour water into the saucepan without disturbing the coin. Are you now able to see the coin? Why?

6.9 Standing on the edge of a swimming pool, look at someone holding himself upright in the pool by treading water. How do you account for the apparent shortening of the body?

More questions

6.10 An Aborigine standing on a river bank with a spear sees a fish in the water. How does he aim his spear to kill the fish — towards the position where he sees the fish, above or below it? Explain your answer.

6.11 What causes waves to break as they come in towards a beach? Have you ever been surfing when the waves are "dumping"? What causes waves to "dump"?

6.12 Explain, with the aid of diagrams, why you cannot see things clearly through "rippled" glass.

Test yourself (chapter 6)

Choose the best answer to each of the following questions and write its letter in your workbook.

1. The arrow in the diagram 6.17 represents a beam of light striking a rectangular glass prism. On entering the glass, the beam
   (a) bends towards A
   (b) bends towards B
   (c) is totally absorbed
   (d) continues without bending.

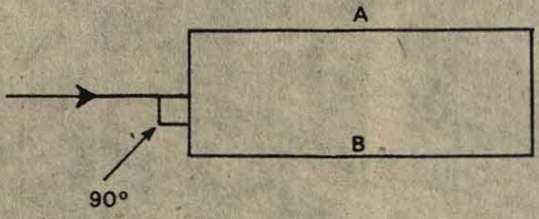


Figure 6.17

2. The arrow in figure 6.18 shows the direction in which a wave is travelling across the water in a tank. If the wave encounters a shallow region at the line PQ, then
   (a) it will be completely reflected without change in speed
   (b) it will continue in the same direction but with reduced speed
   (c) it will be partly refracted towards P (to the left) and partly reflected
   (d) it will be partly refracted towards Q (to the right) and partly reflected.

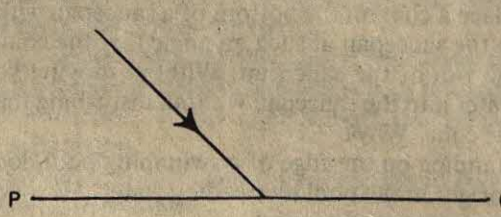


Figure 6.18

3. Figure 6.19 shows a ray of light striking the face of a glass prism at point P. The most probable path for the ray is
   (a) PQT
   (b) PRT
   (c) PRV
   (d) PSV
   (e) PSW.

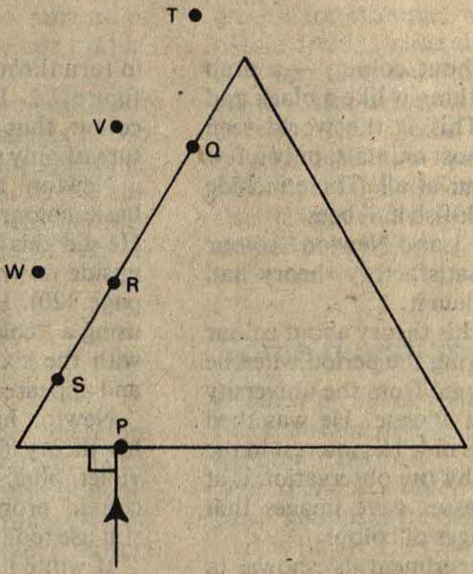


Figure 6.19

7

Colour

Imagine a world without colour — a drab world in which everything is like a black and white photograph. This is the world seen through the eyes of most animals; only a few animals see any colour at all. These include humans, the apes, goldfish and bees.

Until the time of Isaac Newton, colour was a mystery; no satisfactory theory had been proposed to explain it.

Newton developed his theory about colour in 1664. This was during the period when he was forced to stay home from the university because of the Great Plague. He was then only twenty-two years old. His interest in the subject was aroused by the observation that thick magnifying glasses gave images that were distorted by fringes of colour.

Newton's first experiment is shown in figure 7.1 (facing page 120). In it the prism separates white light into a band, or spectrum, of colours — red, orange, yellow, green, blue and violet. This gave Newton the idea that white is not one colour but a mixture of different colours.

Newton thought that there might be more colours than the six he found in the spectrum. To test this idea he passed each colour in turn through a second prism, as shown in figure 7.2. However, this gave him no new colour, thus proving that white light is a mixture of only six basic colours.

Newton actually recombined these six basic colours to produce white light again. He did this by using a second prism turned upside down as shown in figure 7.3 (facing page 120). He also produced white light by using a "colour disc". This disc was painted with the six basic colours of the spectrum and appeared white when spun very rapidly.

Newton had provided strong evidence for his theory that white light is a mixture of violet, blue, green, yellow, orange and red in certain proportions. This is the theory we still use today.

If white light is a mixture of only six colours, how then do we explain the existence of the thousands of different colours we see around us every day?

Coloured glass

Let us examine a piece of purple glass. Purple is not one of the basic colours of the

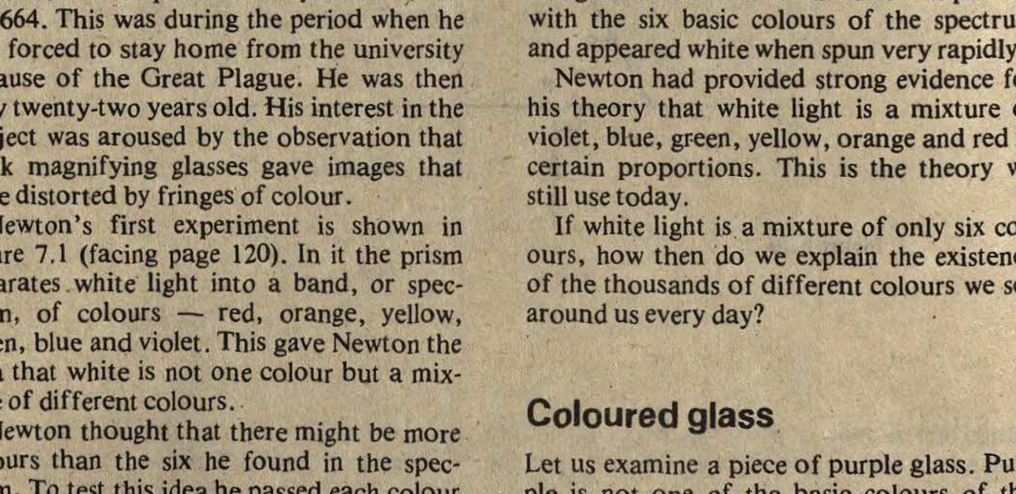


Figure 7.2: Newton's way of trying to divide the spectrum into additional colours. The second prism gave no new colour; it merely spread the existing colours over a wider band.

spectrum. How then do we explain why we see such a colour?

Suppose we shine on the glass, in turn, beams of red, orange, yellow, green, blue and violet light. We find that two of these colours pass through. They are red and blue; the remainder are apparently absorbed. Therefore, when we hold a piece of purple glass up to white light, only red and blue come through into our eyes. A mixture of these two colours causes us to see purple. (See figure 7.4, facing page 121.)

This is the explanation of the multitude of colours around us; most are mixtures of two or more of the basic colours of the spectrum.

It is an interesting experiment to test coloured filters to see what basic colours they contain. This is done in experiment 7.1, using a direct vision spectroscope.

Coloured paper

Paper is opaque. White paper therefore reflects all colours of the spectrum. Black paper absorbs all colours; it reflects none. Blue paper reflects only blue; it absorbs all other colours. Similarly, red paper reflects only red. Purple paper, however, reflects two colours — red and blue; it absorbs orange, yellow, green and violet.

Table 7.1 gives a summary showing what is seen when various pieces of coloured paper are illuminated by lights of different colours.

Table 7.1: Effects of coloured lights on coloured papers

Colour of paper	Appearance of paper in			
	red light	yellow light	green light	blue light
pure blue	black	black	black	blue
pure red	red	black	black	black
pure green	black	black	green	black
purple	red	black	black	blue

When we call a piece of paper "pure blue", we mean that it reflects only blue light. However, the eye is easily deceived. It cannot always distinguish between a pure blue object and another object that appears blue yet has traces of other colours in it. See figure 7.4 (facing page 121).

You probably know how difficult it is to match knitting wools. How many different greens, for example, would it be possible to obtain from a large department store? The only way to be sure that two skeins of wool are the same colour is to examine them side by side. This should be done in daylight. Electric light is not the same as daylight and two colours that appear to be the same under electric light could appear different when examined in daylight.

Some questions answered

Is black a colour? Black is not a colour. A black surface reflects no light; it absorbs all light that falls on it.

Why is the sky blue? Small particles in the earth's atmosphere scatter any blue light that strikes them. They do not scatter the other colours of the spectrum. The sky therefore contains a lot of blue light scattered in all directions. This is the reason for its blue appearance. To spacemen, once they are out of the earth's atmosphere, the sky appears black. There are no particles in space to scatter the blue light.

What colours make brown? A brown surface has very little colouring material in it. It is almost black but reflects a little yellow or orange.

Why is the froth on beer white? A glass of beer appears brown because it absorbs all colours except those that give the sensation of brown. Froth is made up of thousands of tiny bubbles. When white light shines on these bubbles it does not penetrate very far. If it is not reflected by the first few layers, it is reflected by layers deeper down. The walls of the bubbles are so thin that very little colour is absorbed. Therefore, since practically all colours are reflected, the froth appears white. Snow appears white for the same reason; so also does a heap of powdered brown glass.

What causes a rainbow? For a rainbow to be seen, sunlight must be shining on raindrops. The raindrops disperse the sunlight into its spectrum of colours. (See figure 7.5.) The sunlight is reflected internally at the back of each raindrop. Therefore we see a rainbow only when the sun is behind us. Also we see the highest bows when the sun is lowest in the sky.

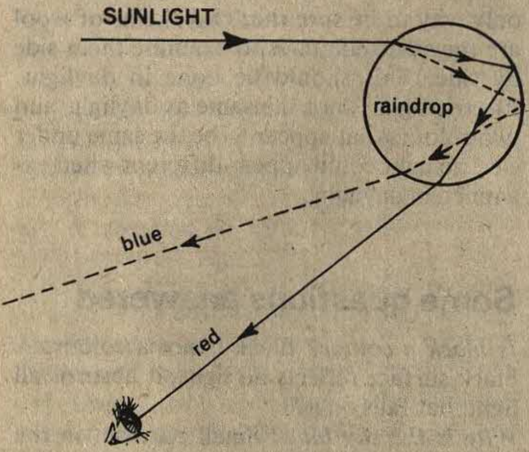


Figure 7.5: The formation of a rainbow. Only red light is passing into the eye of the observer from this particular raindrop. A raindrop that transmits blue light to the observer would be lower in the sky.

Why does a prism separate the colours?

After Newton's discovery about colour, many people, including Newton himself, tried to find out why a triangular prism separated white light into its colours.

Some investigators suggested it was because white light was a mixture of differently coloured particles. The particles of each colour were the same but different from the particles of other colours. The red particles were the heaviest and therefore deviated the least when they entered the glass. This particular theory was the most popular one and was accepted for over 150 years.

An opposing theory suggested that the different colours had different wavelengths. For example, red light had the longest wavelength and violet the shortest. The shorter the wavelength of the light, the more it was refracted as it entered the glass.

In chapter 9 we discuss the additional evidence that led people to discard the particle theory in favour of the wave theory of light.

EXPERIMENT

7.1

Analysing white light

Each group will need:

- ray box
- power pack
- equilateral triangular prism
- white screen

What to do

- Place the ray box on a book on a bench so that the beam of light from it does not strike the surface of the bench.
- Insert the metal plate containing the slits into the box and choose a slit to give a single narrow beam.
- Project the beam on to a screen placed about 90 cm away.
- Place the prism on the book in front of the slit, as in figure 7.1. Rotate the prism until you get the clearest spectrum of colours on the screen.

Questions

7.1 In what position did the prism give the clearest spectrum — the position for maximum deviation of the beam or a position where the deviation of the beam was a minimum?

7.2 Which colour was deviated the most and which the least?

EXPERIMENT 7.2

What colours are absorbed by various coloured filters?

Each group will need:

- ray box
- power pack
- equilateral triangular prism
- white screen
- various pieces of coloured glass or transparent coloured plastic

What to do

- Set up the apparatus used in experiment 7.1 in a darkened corner of a room. Obtain the clearest possible spectrum on the screen.
- Insert a coloured filter between the prism and the screen, fairly close to the prism. Note what colours still appear on the screen and which are missing, that is, absorbed by the filter. Record your observations in a copy of the table given below.
- Repeat, using other selected filters.
- Repeat, using pairs of filters held together.
- Try to predict what you will see before you carry out each test.

Apparent colour of filter tested	Colours transmitted	Colours absorbed

Questions

7.3 Did you find any filters that were monochromatic, that is, transmitted only one colour? Which were they?

7.4 Did you find, for example, a green filter that transmitted both green and blue? Such a filter would appear green because it transmitted much more green than any other colour.

EXPERIMENT 7.3

What colours are present in various coloured wools?

Each group will need:

- The same apparatus as for experiment 7.1, with the addition of a collection of strands of wool of different colours.

What to do

- Set up the apparatus in a darkened room. Obtain the clearest possible spectrum.

- Select a strand of, say, red wool. Hold it in each of the colours in the spectrum on the screen in turn. Copy the following table into your workbook and record your results in it.

Apparent colour of strand	Colour of strand in					
	red light	orange light	yellow light	green light	blue light	violet light

Note: A pure red wool should show up as red when placed in red light but black in all other sections of the spectrum. Some colours, however, are not pure; they will reflect more than one colour.

- Repeat this procedure with strands of other colours.

Colour

- **White light is a mixture of the colours red. orange, yellow, green, blue and violet in certain proportions.**
- **A piece of pure red glass transmits only red light; it absorbs all other colours.**
- **A piece of pure red paper reflects only red light; it absorbs all other colours.**
- **Most of the colours seen around us are mixtures of two or more of the basic colours of the spectrum.**

Spelling list

absorb
absorption
dispersion
illuminate
incidence
opaque
prism
spectrum
transparent

Things to do

7.5 Stand with the sun behind you and spray water from a garden hose into the air. Do you produce a rainbow? What colour is at the top of the bow?

7.6 Extract the green colouring matter from some leaves by crushing the leaves in a little alcohol. Make a concentrated solution in a small glass container (a rectangular one). Test what colours are present in the chlorophyll. Is chlorophyll a pure green? Suggest what might be happening when leaves change from green to yellow in the autumn.

7.7 Place a dish of water in sunlight. Lean a small pocket mirror against one of the inner sides of the dish so that it is totally beneath the water. Hold a sheet of white cardboard above the water to one side so that it catches the spectrum reflected out of the water by the mirror. You may have to adjust the position of the mirror to obtain a good spectrum. Is the spectrum the same as the one produced by the prism?

7.8 Ask your partner to hold a bright darning needle at right angles to the direction of the sun's rays. Hold a triangular glass prism close to your eye with the top and bottom sides parallel to the needle. Look through the prism towards the needle. By rotating the prism you will eventually see a spectrum. Is it any different from the one seen in experiment 7.1?

More questions

7.9 Name the colours of the spectrum, commencing with the colour that is refracted most by the glass.

7.10 A red "V" is painted on white cardboard. What is the appearance of the cardboard in (a) white light, (b) red light, (c) green light?

7.11 A red "V" is painted on green cardboard. What is the appearance of the cardboard in (a) white light, (b) green light, (c) red light, (d) blue light?

7.12 What do you think happens to the energy of the light that is absorbed by coloured glass?

7.13 Why are fog lights for cars yellow? (R)

7.14 Why is the setting sun often red? (R)

7.15 Why does deep water appear blue on a clear sunny day? (R)

7.16 Why does shallow water appear green? (R)

7.17 Comment on the statement: "Cats can see in the dark." (R)

7.18 Why is it that people with a pink tinge in their cheeks appear ghastly under certain fluorescent lights?

7.19 Why do some butchers put neon lights in their display windows?

7.20 Why is it that objects that appear to be the same colour in artificial light may appear different in natural light?

7.21 It is desired to find out whether cows see colour. Can you suggest an experiment for this purpose? (R)

7.22 Infrared and ultraviolet are invisible forms of energy radiated from the sun. Where do you think they would occur in relation to the visible spectrum? (R)

Test yourself (chapter 7)

Write the answers in your workbook.

1. Which colour of the spectrum is refracted most by a triangular prism?
2. Would you see the larger rainbow in (a) early afternoon, or (b) late afternoon?
3. Which colour is uppermost in a rainbow?

4. What colour would a white flower appear when viewed in
   (a) sunlight
   (b) pure red light
   (c) pure blue light?
5. What colour would a pure blue flower appear in
   (a) sunlight
   (b) pure red light
   (c) pure blue light?
6. A white object is viewed through a piece of pure red glass. What colour would the object appear when illuminated by
   (a) sunlight
   (b) pure red light
   (c) pure blue light?
7. A red object is viewed through a piece of pure red glass. What colour would the object appear when illuminated by
   (a) sunlight
   (b) pure red light
   (c) pure blue light?
8. An apparently blue pullover appears green in pure green light. What conclusion do you come to about the colour of the pullover?
9. What colour would a red flower appear if viewed through pieces of pure red and pure blue glass held together?
10. The French flag has three vertical bands — blue, white and red. Assuming these are pure colours, what would be the appearance of the flag if it were illuminated by
    (a) pure red light
    (b) pure blue light
    (c) pure green light?

8

Lenses

Most living things are sensitive to light. Green plants push their shoots towards it. They will do this even when obstacles are placed in their path. Some animals, like the common earthworm, have no eyes but sense the presence of light through sensitive cells in their skins. Most animals, however, have eyes. These give the animals a picture of what is going on around them.

An important part of any eye is the lens; it focuses a picture on light-sensitive cells at the back of the eye. Our own eyes each have two lenses: the clear curved front of the eye, called the cornea, is one and the lens in the eyeball behind the iris is the other.

How a lens works

A lens works the way it does because of its special shape. We can consider a lens to be made up of two triangular prisms.

Figure 8.1 shows how a ray is refracted when it passes through a single triangular prism. As the light passes into the glass it is bent away from the surface; it is bent towards the surface as it emerges again into the air.

Figure 8.2 shows what happens when parallel rays of light pass through two triangular prisms arranged in different ways.

Figure 8.2A corresponds to a converging lens and figure 8.2B to a diverging lens. Compare these two figures with the photographs in figure 8.3.

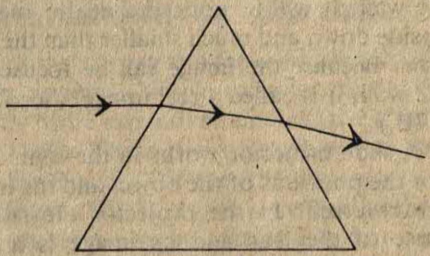


Figure 8.1: A ray of light passing through a single triangular prism of glass.

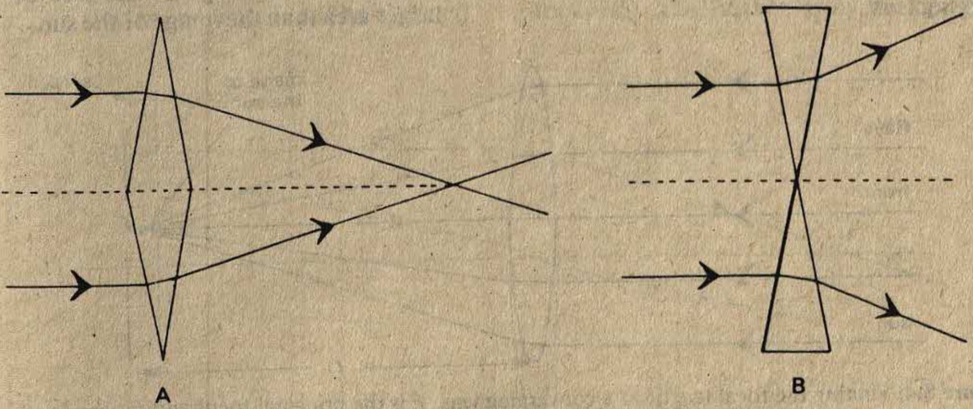


Figure 8.2: Showing what happens when two parallel rays pass through pairs of prisms.

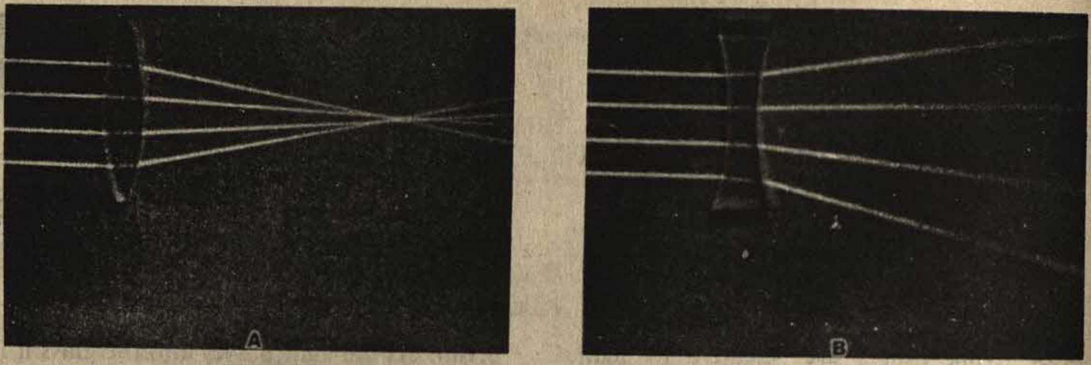


Figure 8.3: Showing the refraction of parallel beams of light as they pass through a converging lens and a diverging lens. Notice that the light rays bend towards the thicker part of the lens in each case.

The converging lens

A converging lens can be used to project an image on to a wall. This is done by choosing part of an inside wall opposite a window and focusing the outline of the window on it. In most cases a clear image will be obtained by holding the lens only a few centimetres from the wall. It will be noticed that the image is upside down and much smaller than the window. Because the image can be focused on the wall, it is called a real image. (See figure 8.7B.)

A slide projector works in the same way, but the positions of the object and the image are reversed. In the projector the slide is close to the lens and its image is a long distance away. The image is also much bigger than the slide. (See figure 8.7A.)

These observations show that, with a converging lens,

- a small image is obtained when the object (the window) is a long distance from the lens
- a large image is obtained when the object (the slide) is close to the lens.

Finding the focal length of a converging lens

The focal length can be found by using the lens to focus an image of the sun on a screen. The distance between the lens and the screen is the focal length. (See figure 8.4.) The lens focuses the heat as well as the light from the sun and will therefore set the screen alight if the image rests on it for too long.

The focal length may also be found by focusing the image of a distant object, such as a tree, instead of the sun. Figure 8.5 shows that the image of the tree covers a larger area than the image of the sun.

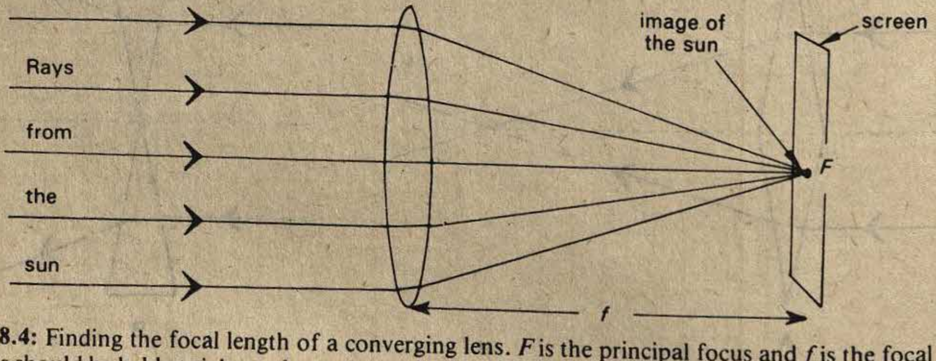


Figure 8.4: Finding the focal length of a converging lens. *F* is the principal focus and *f* is the focal length. The lens should be held at right angles to the sun's rays.

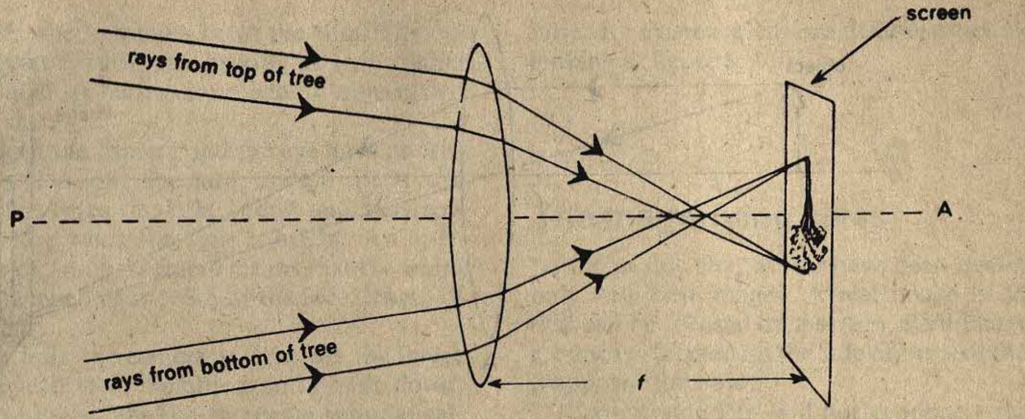


Figure 8.5: Finding the focal length by focusing the image of a distant tree on to a screen. PA is the principal axis of the lens.

Finding the positions of images by diagrams

Figure 8.6 shows the paths of three rays through a converging lens. Ray number 1 goes through without refraction. Ray number 2 is refracted at both faces of the lens. But because the faces at this part of the lens are parallel it emerges parallel to its original direction. Such a ray can therefore be regarded as passing straight through. Ray number 3 is parallel to the principal axis. After refraction it passes through the principal focus, *F*.

Figure 8.7 shows how the three rays just mentioned can be used to find the position of the image of an object that is placed in front of a converging lens. It can be assumed that, because the bottom of the object is on the principal axis, its image will be on the same line. In diagram A the image is magnified and in diagram B it is diminished.

The camera and the eye

Both the camera and the eye have converging lens systems. Simple cameras have a single lens. More expensive cameras have a number of lenses. These give a clearer picture than a single lens. In the eye, the cornea acts as a lens and there is also the lens behind the iris, so the eye may be regarded as having two lenses. (See figure 8.8.)

In the camera, the image is focused on the film by moving the front lens backwards or forwards. The further away the object, the

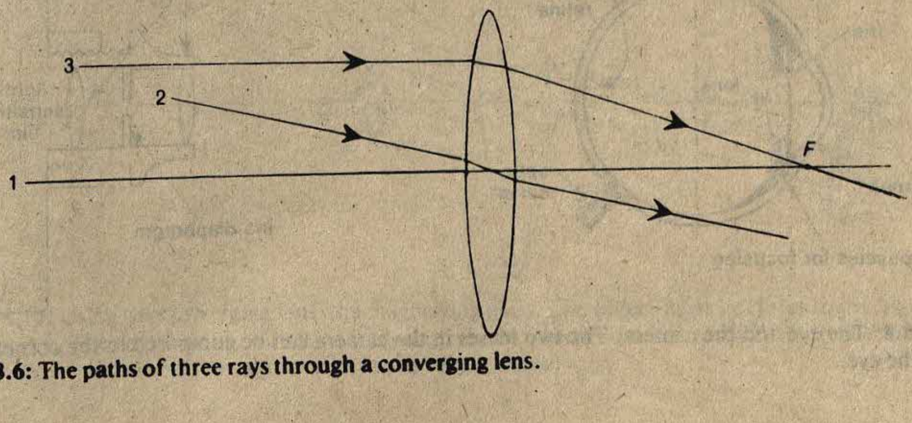


Figure 8.6: The paths of three rays through a converging lens.

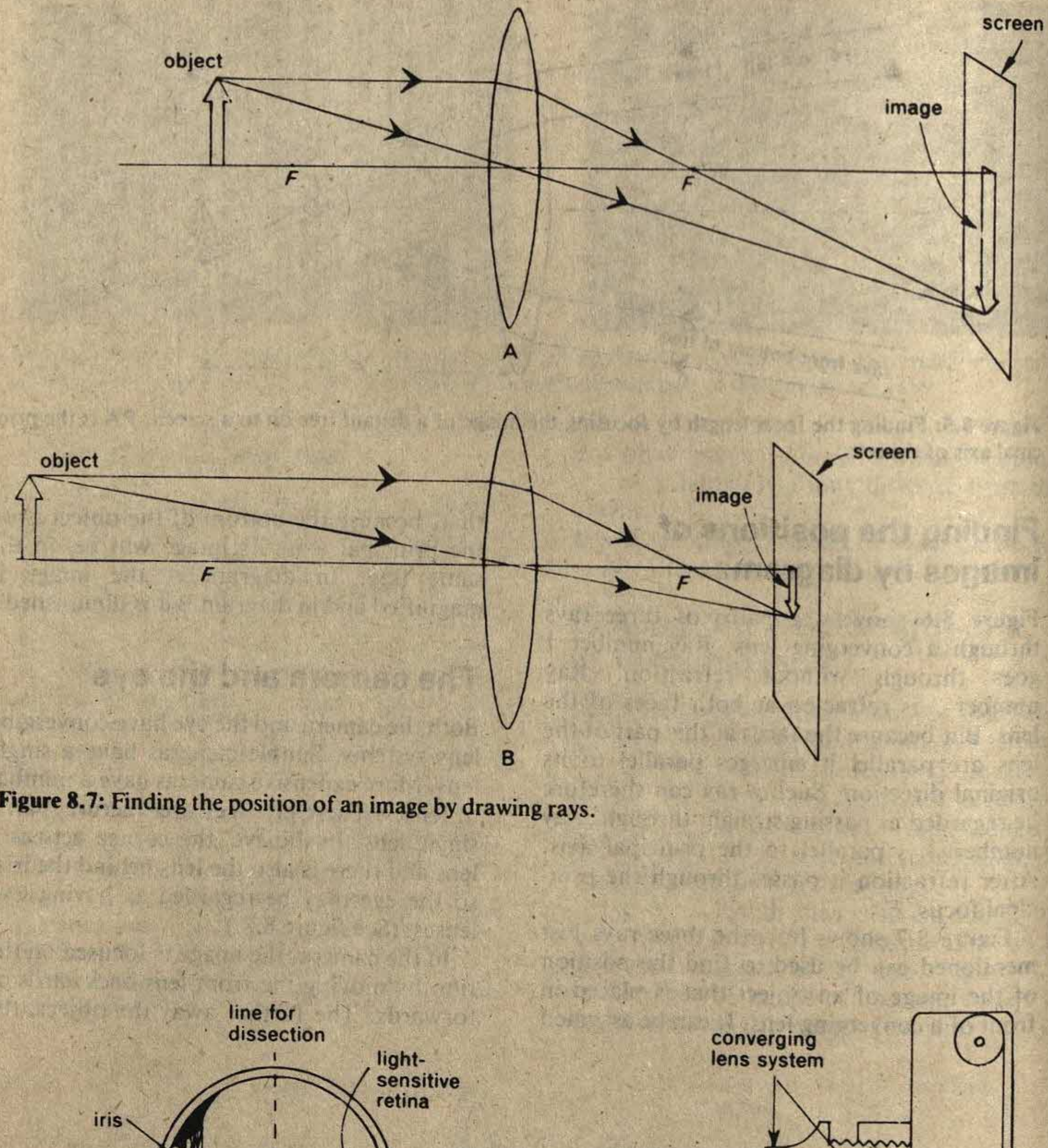


Figure 8.7: Finding the position of an image by drawing rays.

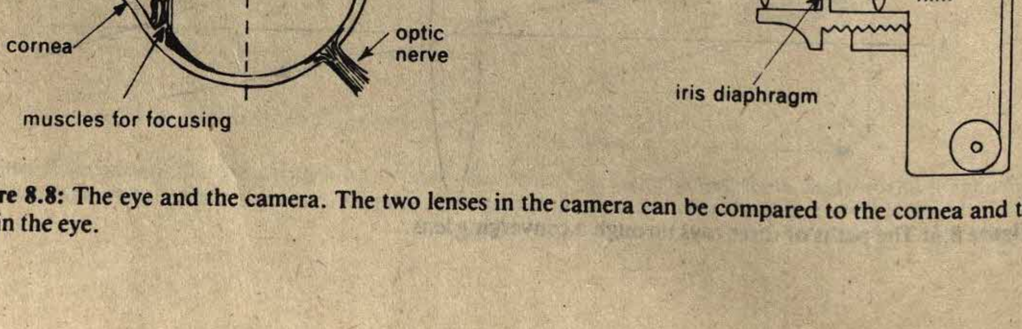


Figure 8.8: The eye and the camera. The two lenses in the camera can be compared to the cornea and the lens in the eye.

closer the lens must be to the film. The eye does its focusing by making its lens thinner or fatter. A fat lens is needed for objects that are close.

Both the camera and the eye have an iris. This alters the aperture; a wide aperture is needed when the light is dull and a narrow aperture when the light is bright. An aperture of *f* 8 on a camera means that the width of the opening is 1/8th of the focal length of its lens.

In both the camera and the eye the image is smaller than the object and upside down. In the case of the eye, our brain automatically compensates for this inversion without our being conscious that it is happening.

As well as being upside down, the image is reversed right to left. This means that an object on our right has its image on the left-hand side of the retina of each eye.

Each eye has a blind spot. This is where the optic nerve joins the retina. The blind spot is on the side of each retina nearer the nose. Its existence can be demonstrated by looking at figure 8.9.

The magnifying glass

So far in this chapter we have been dealing only with real images. A real image is one that can be focused on a screen. Real images are always formed on the side of the lens that is opposite the object.

A converging lens will not produce a real image if the object is too close, that is, if it is closer than the focal length. In this position, however, a virtual image can be seen if we look through the lens towards the object. This image is upright and magnified and on the same side of the lens as the object. This sort of image is obtained when we use a converging lens as a magnifying glass. (See figure 8.10.)

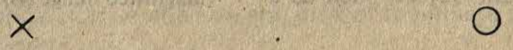


Figure 8.9: Demonstrating the existence of a blind spot on the retina. Close the left eye. Look at the cross with the right eye. The circle disappears at a distance of about 25 centimetres from the eye.

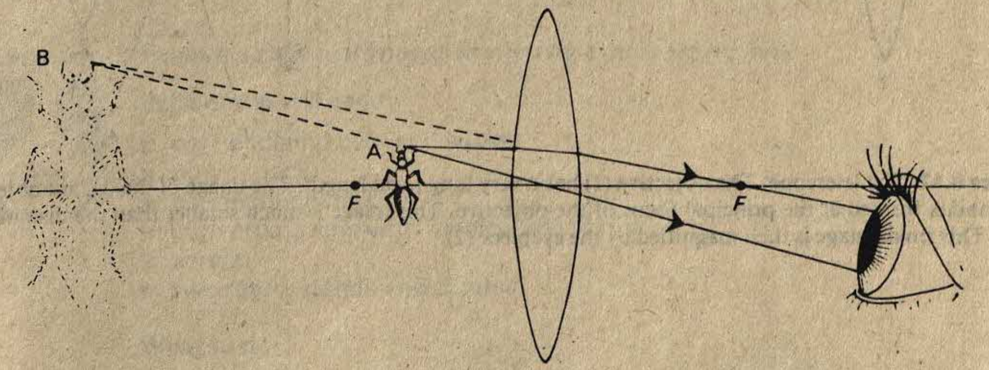


Figure 8.10: Using the converging lens as a magnifying glass. The object must be closer to the lens than the focal length. The rays leaving A that pass through the lens seem to come from B. To make the diagram simpler, rays from the bottom of the object have been omitted.

The microscope

The microscope has a lens at each end of the instrument; these lenses are the objective lens and the eyepiece.

The objective lens has a very short focal length. The object to be magnified is placed just beyond the focal length of this lens. (See figure 8.11.) This produces a magnified real image. This image is further magnified by the eyepiece, which acts as a simple magnifying glass. (See figure 8.10.) For the microscope to work, the eyepiece must be moved up or down until the first image, produced by the objective, is in the correct position to produce the final image. The correct position for the first image is a little closer to the eyepiece than its principal focus. (See figure 8.11.)

The telescope

Like the microscope, the telescope has an objective and an eyepiece. In the telescope, however, the focal length of the objective is very long. This is what makes telescopes so long — up to 15 metres in length.

The image of a distant object, such as a star, is formed at the principal focus of the objective. This image is magnified by the eyepiece in the same way as in the microscope. (See figure 8.12.)

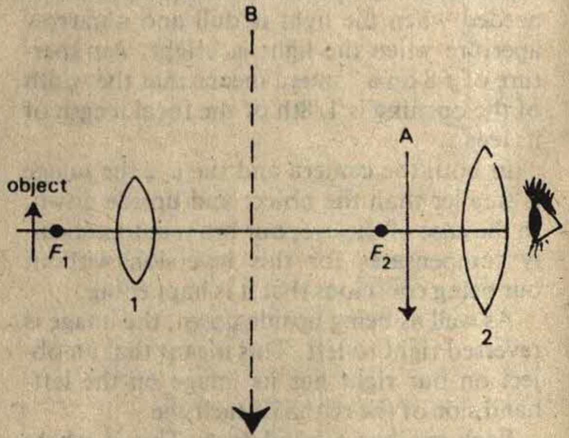


Figure 8.11: The microscope. The object being examined is placed just outside the focal length of lens 1 (the objective). This produces a real magnified image (A). The microscope is adjusted to place image (A) just inside the focal length of lens 2 (the eyepiece). This produces a virtual magnified image (B).

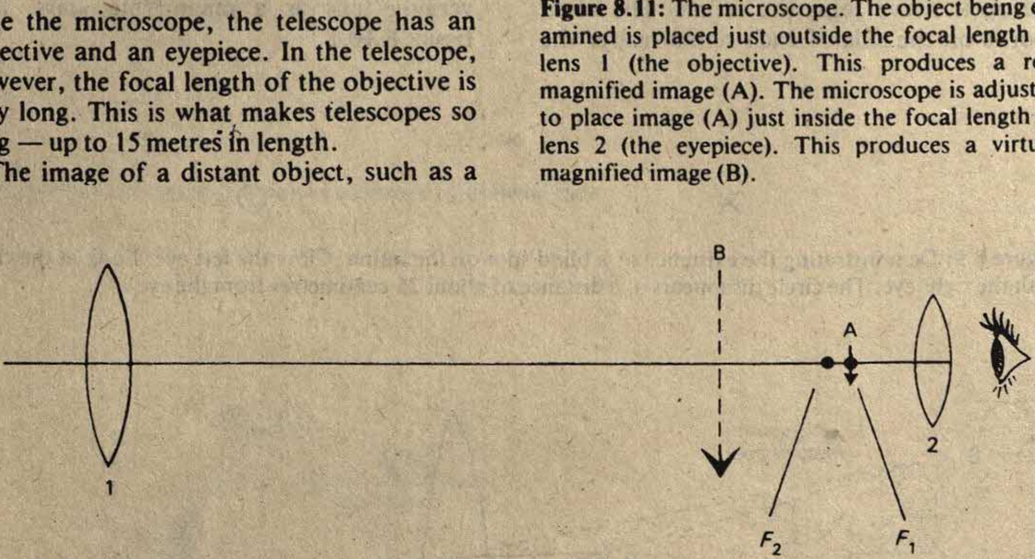


Figure 8.12: The telescope. The objective (1) has a very long focal length. The image of the distant object is real and is formed at the principal focus of the objective. This image is much smaller than the distant object. This small image is then magnified by the eyepiece (2).

EXPERIMENT 8.1

Which lens has the shortest focal length?

Each group will need:

- a number of converging lenses (lenses thicker in the middle than at the sides)
- ruler
- white cardboard for screen
- retort stand and clamp

What to do

- Support the white cardboard vertically in the clamp to act as a screen.
- Face the screen towards a lighted window, preferably one on the far side of the room.
- Select a lens and hold it near the screen so that the principal axis is perpendicular to the centre of the screen. (See figure 8.5.)
- Adjust the distance between the screen and the lens until a clear image of the window appears on the screen.
- Measure the distance between the screen and the lens (the distance shown as *f* in figure 8.5).
- Repeat the procedure with the other converging lenses.

Questions

8.1 Is the image of the window real or virtual? Is it erect or upside down?
8.2 Which lens has the shortest focal length? Is there any relationship between the thickness of a lens and its focal length?

- Now hold one of the lenses at arm's length and look through it towards the window. Close one eye and look at the image of the window for about 30 seconds.

Question

8.3 Does this image seem to be the same as the one you focused on the screen? Where does it appear to be — on your side of the lens or on the far side?

EXPERIMENT 8.2

Examining the real images formed by a converging lens

Each group will need:

- car headlamp bulb and socket
- power pack
- connecting wires
- converging lens with focal length about 20 cm
- screen
- two retort stands and clamps

What to do

- Estimate the focal length of the lens as in experiment 8.1.
- Fit the lens and the screen in the clamp stands and place them on the bench so that they line up with the light, as shown in figure 8.13.

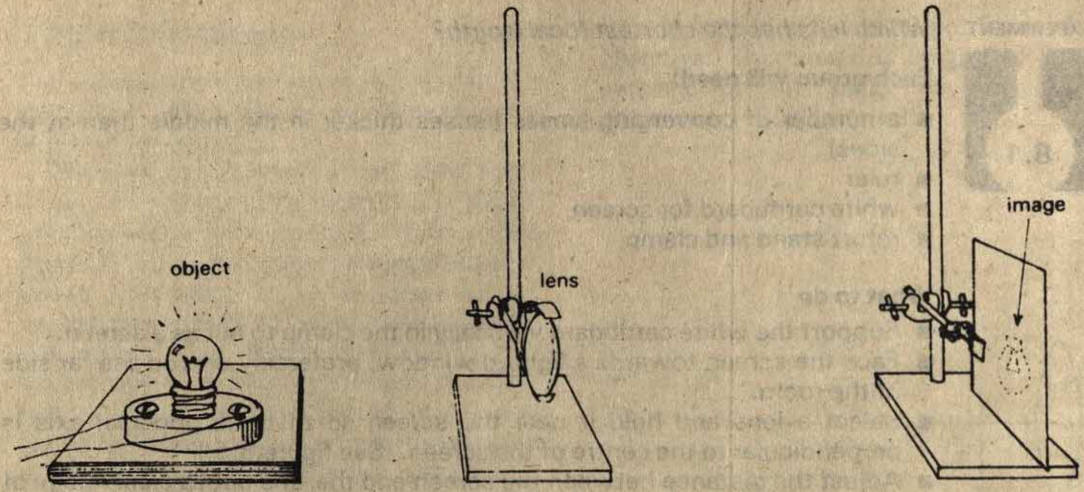


Figure 8.13: How to set up the apparatus for experiment 8.2.

- Place the bulb at a distance twice the focal length from the lens. Move the screen backwards or forwards until a clear image of the bulb is focused on it.
- Draw up a table in your workbook similar to the one shown below.

Focal length of lens	Object distance	Image distance	Description of image		
			Real or virtual?	Magnified or smaller?	Upright or inverted?

- Measure the distance from the bulb to the lens (object distance) and the distance from the lens to the screen (image distance). Record these distances and other observations about the image in the table.
- Repeat with object distances of about 3*f*, 4*f*, 1.5*f* and *f*, where *f* = focal length.

Questions

8.4 Write a general conclusion about the experiment by copying and completing the following statements.

> The image produced on the screen was always ________ and ________. The largest image was produced when the object distance was ________. The smallest image was produced when the object distance was ________. No image was formed on the screen if the object distance was less than ________.

8.5 Where must an object be placed in front of a converging lens to produce (a) a real image, (b) a virtual image?

EXPERIMENT

8.3

Examining diverging lenses

Each group will need:

- a number of diverging lenses (lenses thinner in the middle than at the sides)
- screen
- retort stand and clamp

What to do

- Try to form a real image of the window on the screen, in the same way as with the converging lenses.
- Look at the window through each lens.
- Look through each lens at some print on paper.

Questions

8.6 Were you able to produce a real image with the diverging lenses?

8.7 On which side of the lens is the image when you look at an object through it?

8.8 Were you able to produce a magnified image?

8.9 Is there any relationship between the curvature of the diverging lens and the size of the image it produces?

EXPERIMENT

8.4

Dissecting a bullock's eye

Each group will need:

- bullock's eye
- scalpel
- scissors
- tweezers

What to do

- Notice the muscles for moving the eye. Also notice the iris and the optic nerve.
- Using the pair of scissors, cut the eyeball along the line shown in figure 8.8.
- Note the following:
  - (a) the jelly-like substance inside the eye
  - (b) the retina
  - (c) the muscles that work the lens
  - (d) the optic nerve and the blind spot.
- Cut the cornea and remove the lens.

Spelling list

converge
cornea
diaphragm
diminished
diverge
focus
focusing
iris
lens
lenses
magnify
retina

Lenses

- Lenses bend rays towards their thicker parts — converging lenses towards the principal axis and diverging lenses away from the principal axis.
- A parallel beam of light that is parallel to the principal axis of a converging lens comes to a focus at the principal focus.
- A thick lens generally has a short focal length.
- Real images are formed by converging lenses when the object is outside the focal length.
- Virtual images are formed by converging lenses when the object is closer than the focal length.
- A microscope has an objective lens with a very short focal length.
- A telescope has an objective lens with a long focal length.

Things to do

8.10 Place a glass rod over some small print on a page. Examine the image of the print. Is it real or virtual, magnified or diminished?

8.11 Make a simple telescope using two converging lenses of focal lengths about 20 cm and 5 cm. Place the lenses in clamps and line them up with a distant object seen through a window (such as clouds in the sky). Have the lens with the long focal length as the objective. Move the other lens backwards or forwards until you get a clear image. Is it upside down or upright?

More questions

8.12 What is the difference between a real image and a virtual image?

8.13 Draw a diagram of a converging lens. Mark in the principal axis and the principal focus. Show the refraction of a parallel beam that strikes the lens parallel to the principal axis.

8.14 What is a pinhole camera? Draw a diagram. How can it produce an image without a lens?

8.15 Draw ray diagrams to show the formation by a converging lens of
(a) a real magnified image
(b) a real diminished image
(c) a virtual magnified image.

8.16 What are three similarities and three differences between the eye and the camera?

8.17 How far must a magnifying glass be held from an object in order to magnify it?

8.18 Why is the pupil of the human eye black at the centre? Why does the size of the pupil change from time to time?

8.19 What is the eye's blind spot? Why do we not notice it in ordinary vision?

Test yourself (chapter 8)

1. Copy the table below into your workbook. Complete it by saying whether the image is real or virtual, magnified or diminished in each case.

Instrument	Kind of image	Size of image
(a) camera		
(b) slide projector		
(c) eye		
(d) magnifying glass		
(e) objective of microscope		
(f) objective of telescope		

In questions 2 to 6, choose the best answer and write its letter in your workbook.

2. A virtual image produced by a single lens is
   (a) always inverted
   (b) always smaller than the object
   (c) able to be formed on a screen
   (d) always upright.
3. The images formed by converging lenses
   (a) can be real or virtual depending on the position of the object
   (b) are always virtual and magnified
   (c) are always real and inverted
   (d) are always real.
4. Diverging lenses always produce images that are
   (a) virtual and inverted
   (b) real and inverted
   (c) virtual and upright
   (d) real and upright.
5. A converging lens of focal length 10 cm will form a virtual image when the distance of the object from the lens is
   (a) 20 cm
   (b) 16 cm
   (c) 12 cm
   (d) 8 cm.
6. A converging lens of focal length 20 cm will form a real diminished image when the distance of the object from the lens is
   (a) 10 cm
   (b) 20 cm
   (c) 40 cm
   (d) 50 cm.

9

Theories about light, diffraction and polarization

At the time of Newton and for over a hundred years afterwards, most investigators had decided that light was made up of particles rather than waves.

Two facts made it very difficult for these scientists to accept a wave theory. In the first place, all their observations showed that waves needed something to carry them. For example, water waves are carried by water and sound waves by air. They argued that, if light is made up of waves, something is needed to carry the waves. This means that light should not travel through a vacuum. It is a well-known fact, however, that light does travel through a vacuum.

The second difficulty arose because of diffraction.

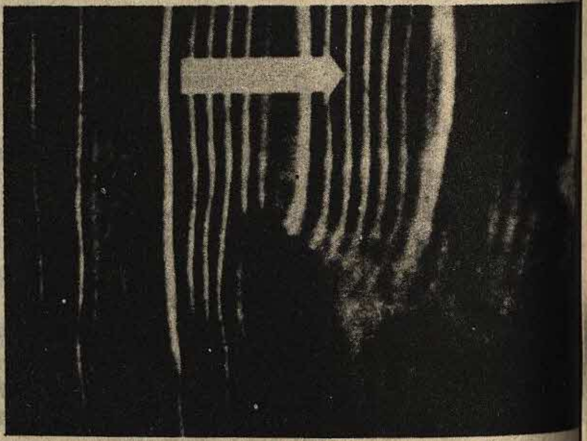


Figure 9.1: Water waves travelling to the right in a ripple tank. Notice how the waves turn as they pass the obstruction.

Diffraction

Diffraction is the way waves travel around corners. The water waves in the ripple tank in figure 9.1 are turning around the corner of the dark obstruction shown in the photograph.

Another example of diffraction is shown in figure 9.2, an aerial photograph. The reef on the headland does not completely shelter the water behind it. Waves coming in from the ocean can be clearly seen turning around the corner and moving on to the beach behind.

Diffraction also occurs when waves pass through a small gap. An example of this is shown in figure 9.3. Notice how the waves fan out as they pass through the small entrance leading to the harbour. The same effect is shown in figure 9.4. This is a photo of waves in a ripple tank passing through a narrow gap.

Diffraction can be demonstrated quite easily with sound waves. For example, a person's voice can be heard around a corner even when there is no chance of echoes, that is, reflection.

Until 1801, diffraction of light had not been observed. It was obvious that light did not turn around corners in the way that water waves or sound waves did. We now

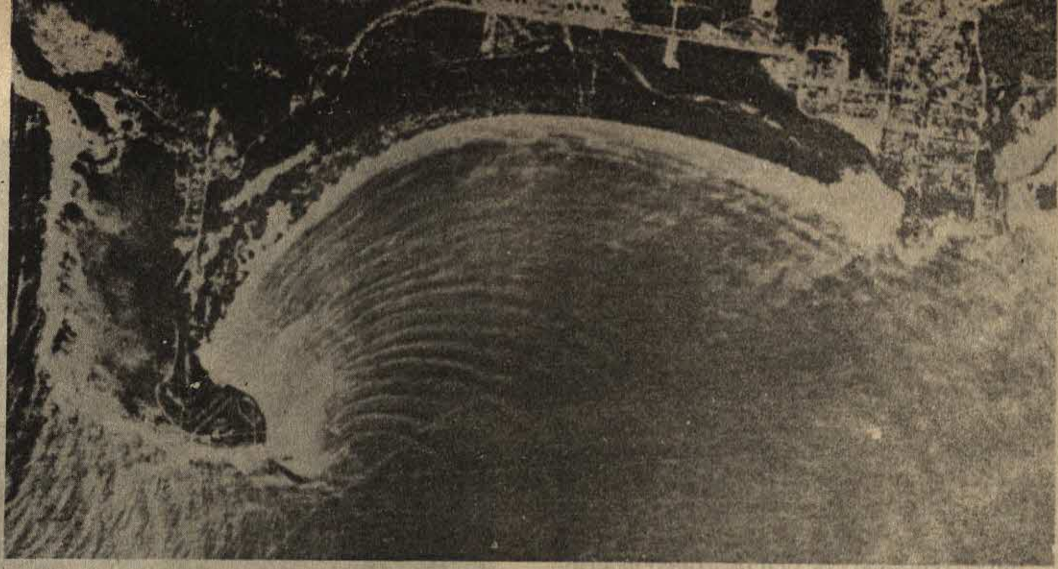


Figure 9.2: An aerial photograph showing diffraction of water waves. Notice how the waves coming in from the ocean on the left are able to curve around the headland and travel on to the beach behind. (Photo courtesy New South Wales Department of Lands)

know why light does not turn around a corner or headland in the way that water waves do. It is because of the extremely short wavelength of light — about 0.00005 cm. However, diffraction of light through gaps may be demonstrated if the gaps are extremely narrow.

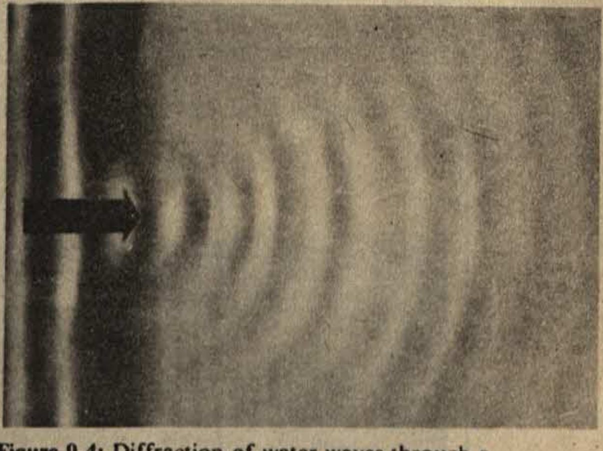
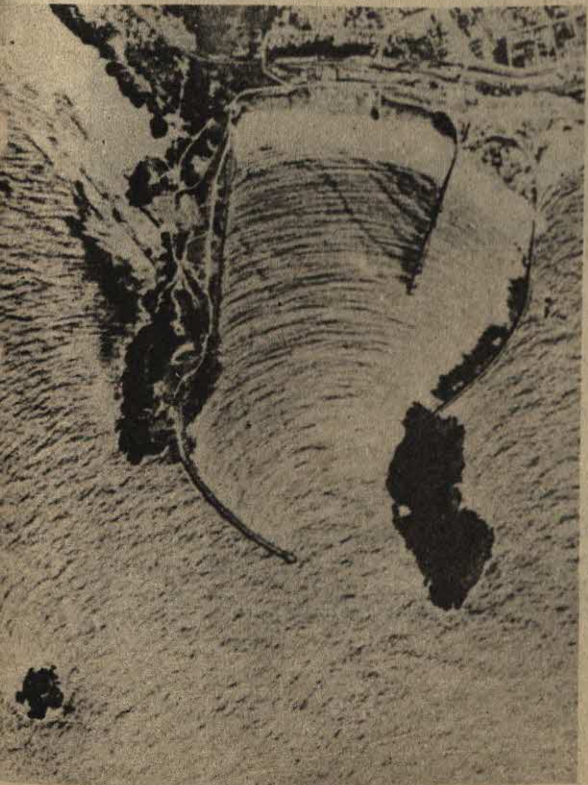


Figure 9.4: Diffraction of water waves through a narrow gap. Note the way the waves fan out from the opening.



◄ **Figure 9.3:** Diffraction of waves through the entrance of Coffs Harbour on the north coast of New South Wales. Notice how the waves fan out as they pass through the opening. There is also diffraction as the waves pass the little island near the harbour. (Photo courtesy New South Wales Department of Lands)

Interference between two waves

Two waves travelling over the same area tend to interfere with one another. This effect can often be seen on an ocean beach. It happens when a wave coming up the beach meets the backwash of the previous wave coming down the beach. When the crests of these two waves meet, a larger wave is formed and water is sometimes flung up into the air. If a crest meets a trough, a cancelling effect occurs and the water is momentarily calm.

Interference may be demonstrated in a ripple tank — see figure 9.5. This photo shows waves passing through two adjacent gaps. As they pass through the gaps they fan out — it is as though each gap is generating a completely new set of waves. These two sets

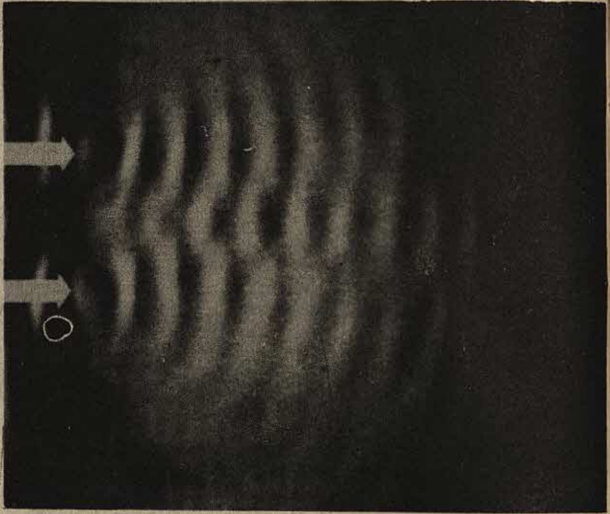


Figure 9.5: The effect produced by the diffraction of water waves through two openings close together.

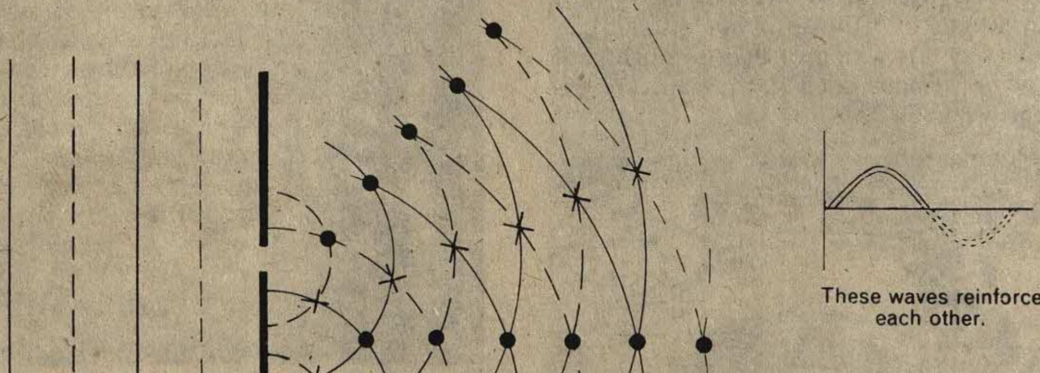

These waves reinforce each other.
These waves cancel each other.
crests
troughs

Figure 9.6: Interference effects caused by two sets of waves passing through each other after diffraction. The crests are shown in full lines and the troughs are shown in broken lines. The waves cancel each other where a crest of one set is in the same position as a trough of the other set. These places are shown by crosses. The waves reinforce each other where crests of each set coincide and also where troughs of each set coincide. These places are shown by heavy dots.

of waves pass through one another and cause interference. The interference results in a pattern of radiating lines.

Figure 9.6 explains why this particular interference pattern is produced. The heavy dots indicate places where the waves are reinforcing one another and the crosses places where they are cancelling one another.

The question an investigator needs to consider is, "Can interference be demonstrated using light?" Until 1801 the answer would have been "no".

Interference observed in light

In 1801 Thomas Young, of Cambridge University, announced that he had observed interference in light. His experiment was similar to that shown with water waves in figure 9.5. He allowed light to pass through two very narrow slits close together. In front of the slits he placed a screen. On the screen he observed a series of bright and dark lines. Young claimed that the bright lines were produced by light waves from the slits reinforcing each other and that the dark lines were produced by waves cancelling each other. A photograph of this effect is shown in figure 9.7.

At first Young's claim was challenged, and his experiment was repeated many times by different people. Eventually it became obvious to all that light was being diffracted in the experiment. The reason it had not been observed before was that no one had allowed for the extremely short wavelength of light. This required the use of very narrow slits.

Diffraction cannot be produced by using particles. Two parallel streams of particles coming through separate openings cannot possibly interfere with one another. For this reason it was obvious that the particle theory of light had to be discarded in favour of a wave theory.

Young's experiment indicated that light must travel as waves. However, it did not indicate whether these waves are transverse like water waves or longitudinal like sound waves. The observation of polarization solved this problem.

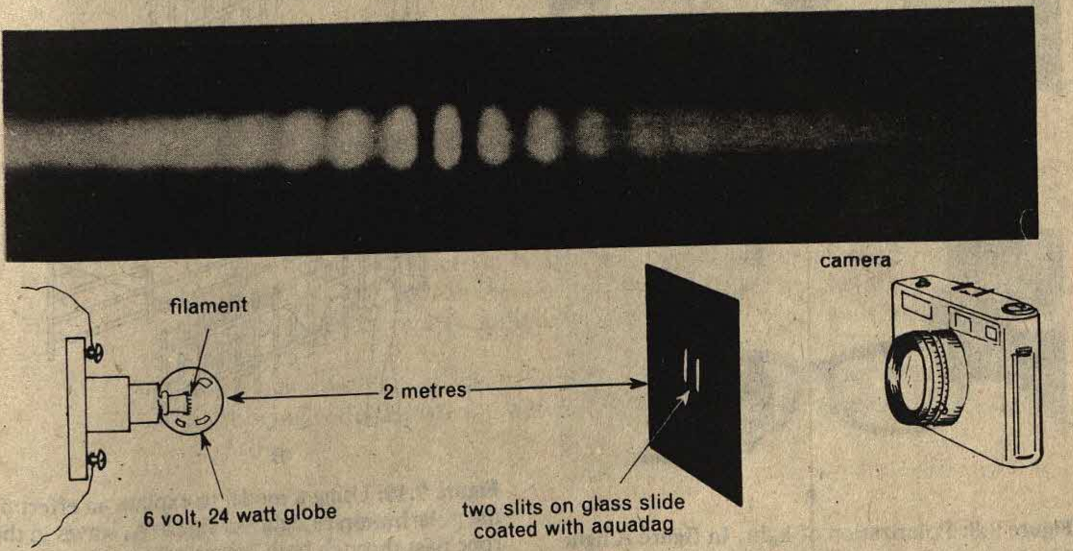


Figure 9.7: A photograph of bright and dark lines. These were formed by diffraction of light by two slits close together on a glass slide. The photograph was taken by pointing the camera towards the slits, as shown in the diagram.

Polarization of light

Figure 9.8 shows the effect of placing two pairs of polaroid glasses together. If one pair of glasses is held fixed and the other pair is rotated, a position is reached where light does not pass through.

Polaroid material is composed of chain-like molecules arranged parallel to one another. It is therefore possible to place two pieces of the material one on top of the other in such a way that the lines of the molecules in one piece are at right angles to the lines in the second piece. This is shown in figure 9.9. In such positions the two pieces together become opaque.

The easiest way to explain this effect is to say that light travels as a transverse wave. The first piece of polaroid material restricts the passage of light to those waves oscillating in the same direction as the lines of molecules. (See figure 9.10.) These waves are unable to pass through the second piece of polaroid material if the lines of molecules in it are at right angles to the lines in the first piece.

If light travelled as a longitudinal wave it would be able to pass through the two pieces

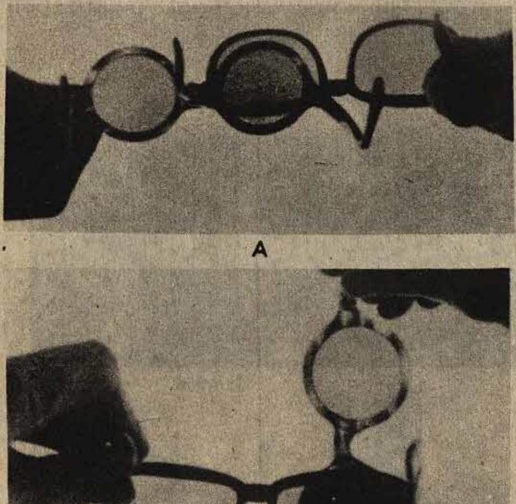


Figure 9.8: Polarization of light. In figure A light passes through two polaroid lenses. In figure B one lens has been turned through 90°, thus blocking the light that comes through the other lens.

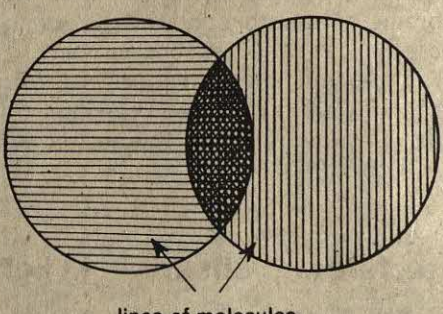


Figure 9.9: Showing how two pieces of polaroid material can be placed against each other to prevent light from passing through.

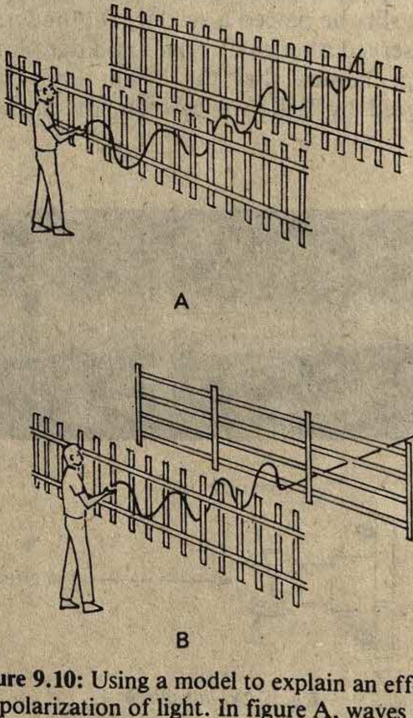


Figure 9.10: Using a model to explain an effect of the polarization of light. In figure A, waves in the rope pass through both fences because the palings are lined up in the same direction. In figure B, the waves are blocked by the second fence because the rails are at right angles to the wave.

of polaroid material no matter what the position of the second piece compared with the first. This is because the oscillations of a longitudinal wave are along the line of the direction in which the wave is travelling.

The fact that light can be polarized indicates that it travels as a transverse wave. But how do we apply this idea to the fact that it can travel through a vacuum? Modern theories about light state that, although it travels as a transverse wave, it does not need a material to carry it. Today scientists think of light as being made up of small packets of waves. These packets are called photons.

Light, diffraction and polarization

- Diffraction is the bending of waves as they pass around the edge of an obstruction. It is also the fanning out of waves as they pass through a narrow gap.
- Diffraction can occur with both transverse and longitudinal waves.
- Polarized material is made of molecules arranged in one direction only.
- Diffraction of light indicates that light travels as waves.
- Polarization of light indicates that it travels as a transverse wave.

Spelling list

cancel
diffraction
interference
longitudinal
oscillation
photon
polarization
polaroid
reinforce
ripple

Things to do

9.1 Hold two pencils vertically about 5 mm apart. Close one eye and with the other eye look through the gap between the pencils at a fluorescent light. Gradually bring the pencils together until they are almost touching. You will see one or two dark lines parallel to the gap. This is an effect similar to the one shown in figure 9.7.

9.2 Look at oil patches on a smooth bitumen road on a wet day. Do you see patterns of colour? This effect is due to the interference of waves — the wave reflected off the top of the oil and the one off the surface of the water beneath the oil. You can sometimes see the same effect with soap bubbles in sunlight.

9.3 Use a pair of polaroid glasses to reduce glare coming off water. Much of the light being reflected off the water is polarized, and the glasses absorb a good deal of it.

More questions

9.4 Draw a line of dots to represent a longitudinal wave. What is the wavelength of the wave you have drawn?

9.5 Draw a diagram of a transverse wave with a wavelength of 4 cm and an amplitude of 2 cm.

9.6 Draw another diagram of a transverse wave with the same wavelength but with more energy than the wave drawn in question 9.5.

9.7 What is meant by diffraction? Using a clock and a piece of sound-proof board, how would you show that sound waves can be diffracted?

9.8 How do polaroid sunglasses reduce the intensity of light coming into the eyes?

9.9 The following are some properties of light.

(a) Light travels in straight lines.
(b) Light is reflected so that the angle of reflection equals the angle of incidence.
(c) A point source of light casts sharp shadows.
(d) Light can be refracted.
(e) Light can be diffracted.
(f) Light can be polarized.

Suppose that three theories of light have been suggested to explain these properties. These theories are:

- a particle theory
- a transverse wave theory
- a longitudinal wave theory.

Which of these theories can explain each of the properties listed? You may list more than one theory for each property.

Test yourself (chapter 9)

Write the answers in your workbook.

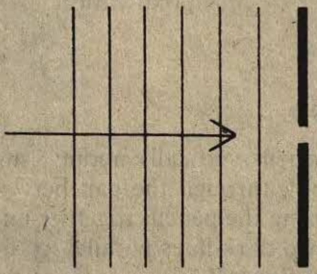


Figure 9.11

1. Figure 9.11 shows a series of waves approaching a narrow gap. Copy the diagram into your workbook and show the wave pattern on the right-hand side of the gap.
2. (a) Draw a diagram of a transverse wave with a wavelength of 3 cm and an amplitude of 1 cm.
   (b) On the diagram just drawn, draw a second wave in a position where it would cancel the first.
3. Repeat 2(a) and add a second wave, this time placing it in a position where it would reinforce the first.
4. Copy and complete this sentence:
   A light wave is polarized when the oscillations of the wave are taking place in only one _______.
5. Copy and complete this sentence:
   Polaroid glasses reduce glare because the light reaching the wearer's eyes has been _______.

10

Coordination

If you speak to a friendly dog, it wags its tail. If you are hungry, the smell of a steak cooking makes your mouth water. If a ball is thrown to you, you catch it. In each of these cases a stimulus to one part of the body causes an action in another part. The working together of different parts of the body in this way is called coordination. In this chapter we will discuss how coordination is brought about.

Figure 10.1: A funnel-web spider aroused and prepared to strike. What stimulus caused it to respond in this way? Was it noise, vibration of the ground, the sight of an intruder, or odour? Is a spider able to respond to all of these stimuli? Notice the cluster of eyes above the fangs.

Coordination by the nerves

Nerves occur throughout the body. They are made of special cells, along which pulses of electricity can travel.

The nerves are arranged in two separate systems — the central nervous system and the autonomic nervous system. The autonomic nervous system controls such things as digestion and the beating of the heart, which go on even when we are asleep. This system is directed from a part of the brain called the medulla. The remainder of the brain directs the central nervous system.

The brain

The brain is the master organ of the body. It is more complex than any machine ever constructed. It contains some 10 000 million nerve cells. These receive messages from the sense organs of the body to tell the person what is going on about him. The brain also stores information from past experiences. We are thus able to learn, remember and think. We can speak, solve difficult problems and produce creative ideas because of the amazing development of the human brain.

Tremendous amounts of energy are needed to keep the vast number of cells of the brain working. Although it is only about 2 per cent of the body's weight, the brain uses 25 per cent of the oxygen in the blood.

The main parts of the brain are the cerebrum, the cerebellum and the medulla. These are shown in figure 10.2.

The outer, wrinkled part of the cerebrum is called the cortex. It receives sensations from the sense organs. These organs are the skin of the body, the eyes, the ears, the nose and the tongue. In addition, the cortex controls the activity of the body's moving parts.

Quite a large area of the cortex is concerned with the processes of thinking, remembering and problem solving. Since we are superior to other animals in these respects we have a much larger cerebrum. The cerebrum is the part of the brain in which voluntary decisions are made. These decisions are made by using information from different parts of the cortex.

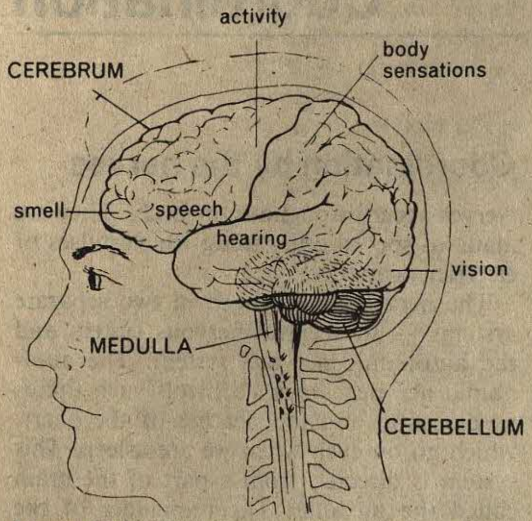


Figure 10.2: The three main divisions of the human brain. The cerebral cortex or "grey matter" of the cerebrum is shown split up into areas. Each of these areas is concerned with some special function.

The cerebellum controls the muscles of the body so that the different parts work in harmony. Injury to a person's cerebellum could cause his movements to become badly coordinated or, in the extreme case, could render him incapable of movement at all.

The medulla, as previously mentioned, is part of the autonomic nervous system. It controls many of the bodily processes, such as the beating of the heart, cell respiration, blood circulation and salivation. These actions do not require any conscious thought. They are said to be involuntary. Injury to the medulla generally results in immediate death.

The spinal cord

The spinal cord carries pulses of electricity to and from the brain. In people, 31 pairs of nerves connect the spinal cord with various parts of the body. Figure 10.3 shows how

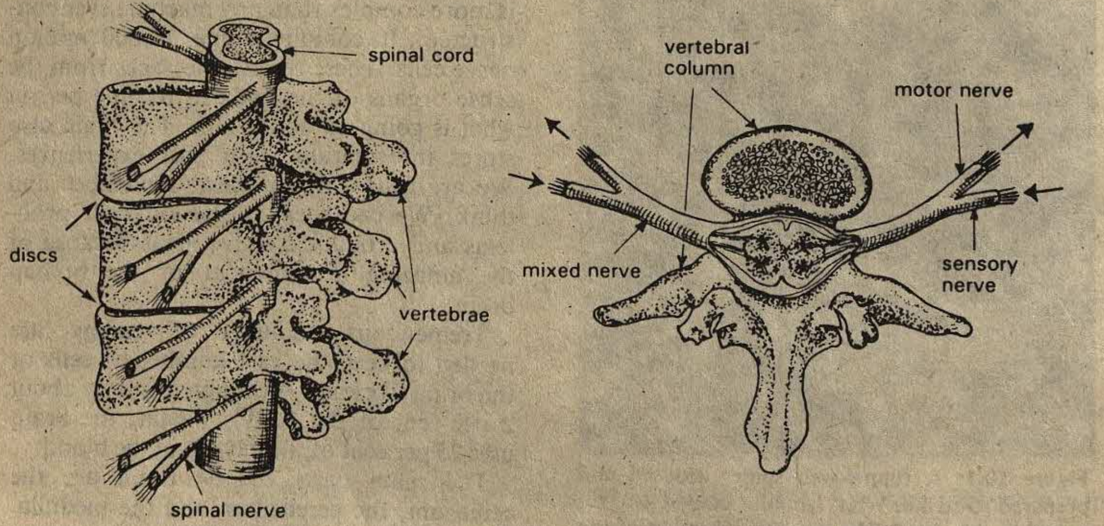


Figure 10.3: A section of the spine showing vertebrae and spinal cord. Notice how a pair of spinal nerves comes out between each pair of vertebrae. Each spinal nerve then divides into a sensory and a motor nerve. A "slipped disc" allows two vertebrae to press on spinal nerves — hence the pain.

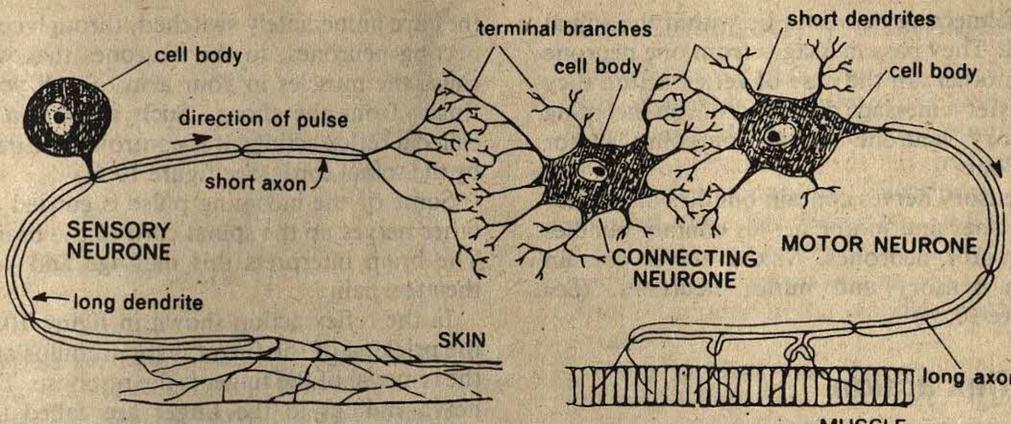


Figure 10.4: Different types of neurones and their parts.

each nerve branches off from one side of the cord in two strands. These strands join and pass out between the vertebrae. The directions in which the impulses travel are shown in the diagram.

Nerves

Each nerve contains a bundle of nerve cells called neurones. A nerve could be compared to a telephone cable that contains a large number of insulated wires leading to the exchange. The neurones in each nerve are insulated from each other by coverings of fat.

The parts of a neurone are shown in figure 10.4. These parts are

- the cell body, which contains the nucleus of the cell
- nerve fibres, called dendrites, that conduct impulses *towards* the cell body
- nerve fibres, called axons, that conduct impulses *away* from the cell body.

Neurones are long cells that conduct pulses of electricity. When a dendrite is stimulated, a pulse passes to the cell body and along the axon to the terminal branches. The terminal branches secrete a small amount of a special substance. This substance may cause a pulse to be set up in another neurone. On the other hand, the substance may cause a gland to secrete or the cells of a nearby muscle to contract.

Neurones that conduct messages *to* the central nervous system are called sensory neurones. They have long dendrites and short axons.

Neurones that conduct messages *from* the central nervous system are called motor neurones. They have short dendrites and long axons.

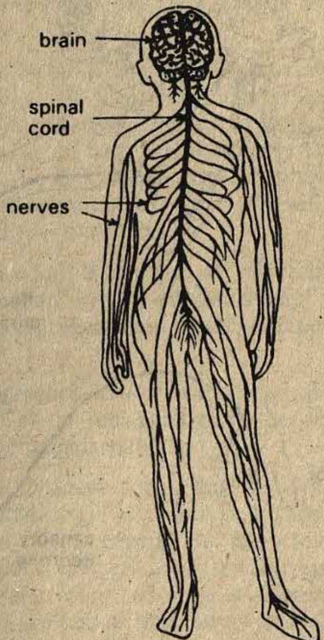


Figure 10.5: The central nervous system, showing the brain, the spinal cord and some of the nerves that pass from the spinal cord to the various parts of the body.

Connecting neurones lie within the spinal cord. They pass messages from one neurone to another. In the case of reflex action they transfer a message directly from an incoming sensory neurone to an outgoing motor neurone.

Sensory nerves contain bundles of sensory neurones and motor nerves contain bundles of motor neurones. Mixed nerves contain both sensory and motor neurones. (See figure 10.3.)

Reflex action

Suppose you prick your finger with a thorn. You pull it away even before you feel the pain. The pulses set up by the injury to the nerve endings of the finger travel along several neurones to the spinal cord. There they are immediately switched, through connecting neurones, to the neurones that will cause the muscles in your arm to pull your finger from the thorn. Such an action is called a reflex action. It is controlled entirely by the spinal cord. (See figure 10.6.)

Some of the incoming pulse is carried by other nerves up the spinal cord to the brain. The brain interprets this message and you then feel pain.

In the reflex action shown in figure 10.6, the pricking of the finger is the stimulus and the removal of the finger is the response. The nerve endings in the finger are called the receptors and the arm muscles that contracted are called the effectors.

Another reflex action is shown in figure 10.7.

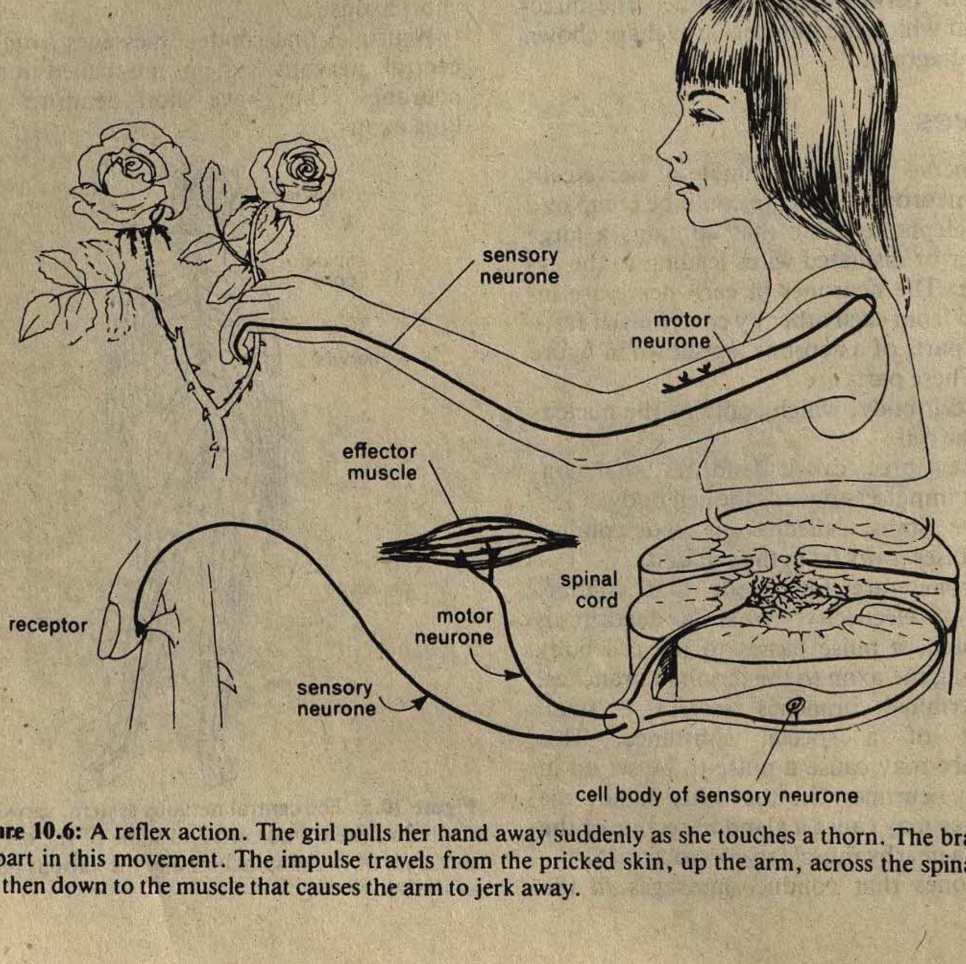


Figure 10.6: A reflex action. The girl pulls her hand away suddenly as she touches a thorn. The brain has no part in this movement. The impulse travels from the pricked skin, up the arm, across the spinal cord and then down to the muscle that causes the arm to jerk away.

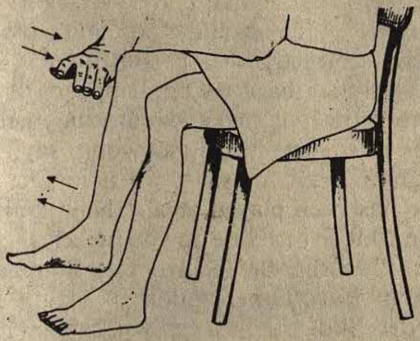


Figure 10.7: Demonstrating a reflex action. The leg jerks upwards when struck below the knee cap. The brain has no control over this movement at all. However, the brain does respond to the feeling when the leg is hit.

Coordination by chemicals

Some internal parts of the body can be made to discharge chemicals into the bloodstream. These parts are called glands. Glandular action is triggered off by certain changes in the surrounding conditions. The chemicals discharged are called hormones and are conveyed by the bloodstream to all parts of the body. Certain organs will respond to a particular hormone in the bloodstream but not to others.

Table 10.1 lists some facts about several of the body's important hormones. Figure 10.8 shows where the main hormonal glands of the body are located.

Table 10.1: Hormones

Hormone	Source of hormone	Comments
Adrenalin	Adrenal glands. In an emergency, these glands are stimulated by impulses from the brain. The impulses may be caused by fright, rage or excitement.	Adrenalin increases the breathing rate and the heart beat. This supplies all cells with extra oxygen. Adrenalin also causes the blood vessels of the digestive system to contract and those in the limbs to expand. More blood is therefore available in the parts of the body that are likely to be used in the emergency.
Insulin	The pancreas. This gland is stimulated by the presence of too much glucose in the blood.	Insulin in the blood causes the liver to change glucose into glycogen. It also helps the cells extract glucose from the blood. This obviously reduces the amount of glucose in the blood. If the pancreas is not working properly, the glucose content of the blood will rise and the respiration of the cells will slow down. This condition is diabetes.
Thyroxin	Thyroid glands, in the neck. These are controlled by another hormone, from the pituitary gland.	Thyroxin controls the rate of cell respiration. Too little thyroxin in the blood causes sluggishness, tiredness, overweight and mental dullness.
Pituitary hormones	Pituitary gland, under the brain.	These hormones control such things as growth, the operation of the reproductive system and the working of other glands in the body.
Sex hormones	Testes and ovaries (see figure 10.8).	The testes produce sperm and the ovaries produce eggs. In addition, both kinds of glands produce sex hormones. These control the growth and development of the characteristics that make males different from females. Some of these characteristics are the breasts of the female and the facial hair and deeper voice of the male. The changes that take place in a woman's body during menstruation and pregnancy are controlled by hormones from both the pituitary gland and the ovaries.

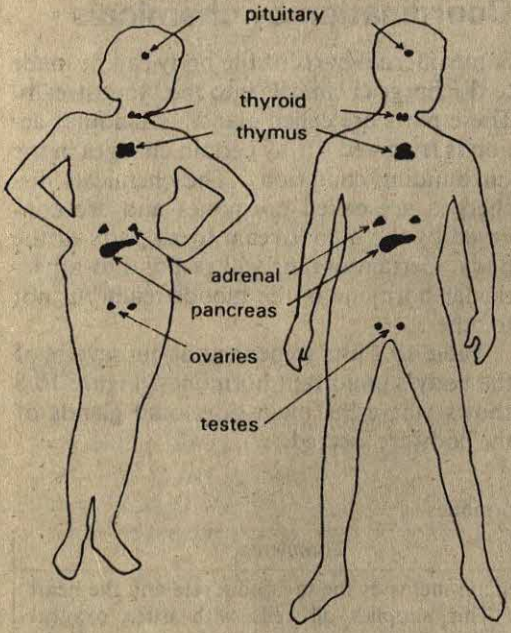


Figure 10.8: Showing the locations of the principal endocrine glands of the human body.

Perception

The brain receives stimuli from the environment through the senses. These senses are sight, hearing, touch, taste and smell. But the brain does more than receive stimuli — it tells us what caused them and whether or not there is any meaning to them.

Imagine, for example, a bird hearing sounds from a record player. To the bird these sounds would be nothing more than noise. Human listeners, however, would be able to tell that they were coming from a record player and, if they had heard the record before, might be able to remember it and even name it. This process of interpreting and explaining sounds is called perception.

However, the brain does not always perceive correctly — it sometimes "imagines" things that have not happened at all. At other times it makes wrong judgments. Have you ever heard someone say, "I thought I heard music", when in fact no music has been played at all? Now look at figure 10.9. Which line do you perceive to be longer? Measure the length of each line and find out if your perception of length has been deceived. If it has, can you explain how it happened?

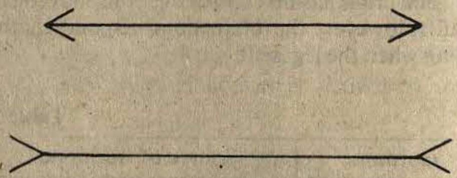


Figure 10.9: Which line do you perceive to be longer? Measure them to check your perception. If you have made a mistake, can you explain why?

We use various clues to estimate the sizes of objects. We know, for example, that the further away an object is, the smaller it appears to be. We also tend to estimate size by comparison with objects in the background. Both of these clues are being used when we make the decision that the boy on the left in figure 10.10 is shorter than the one on the right. Actually both boys are the same height. What caused us to make a wrong judgment?

Our state of mind can also cause us to make mistakes in perception. Half an hour in a dentist's chair seems longer than half an hour at an exciting party. And have you ever been waiting for a friend on a street corner and, quite mistakenly, picked a complete stranger for the person you are expecting to appear?

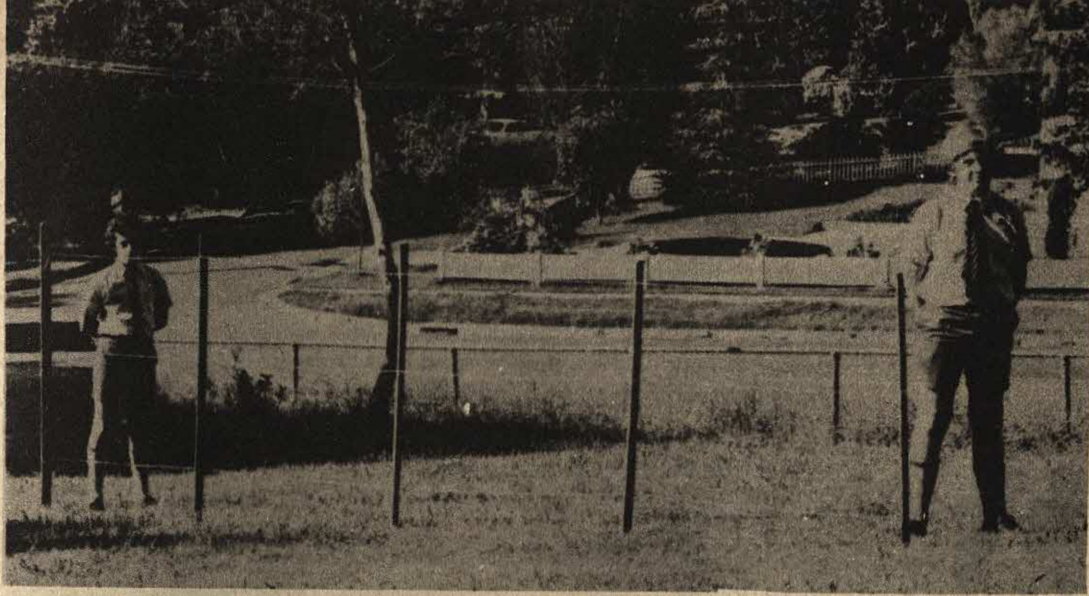


Figure 10.10: An optical illusion. These two boys are the same height, yet the one on the left appears shorter. How was the illusion created?

EXPERIMENT 10.1

Examining a sheep's brain

Each group will need:

- sheep's brain (from butcher)
- scalpel
- forceps
- 4 per cent formalin solution

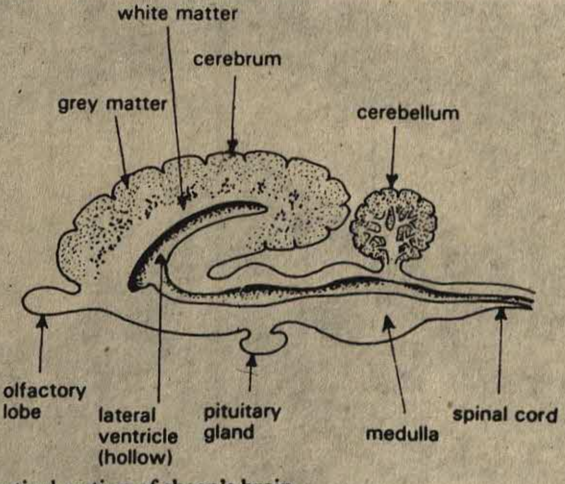


Figure 10.11: Vertical section of sheep's brain.

What to do

- Soak the brain in a 4 per cent formalin solution overnight to harden it.
- Next day, wash the formalin off the brain.
- Cut the brain into equal right and left halves with a sharp scalpel.
- Refer to figure 10.11. Try to locate the various parts named in the diagram. Note the large number of blood vessels.

- Note that the outer layers of the brain are reddish, owing to blood. This area contains the so-called grey matter. The inner core is white matter. The grey matter is mostly cell bodies and the white matter mostly nerve fibres. If you cut across the cerebrum, you will find threads of white matter leading to the outer surface of the brain.

Question

10.1 In what way does the shape of a sheep's brain differ from the shape of a human brain?

EXPERIMENT 10.2

Are all parts of the skin equally sensitive?

Each pair will need:

- five hexagonal pencils, three of them sharp
- two rubber bands

What to do

- Tie four pencils together so that you have two points about 2 cm apart, as shown in figure 10.12.
- Work in pairs with one member of the pair blindfolded.
- Copy the table shown on page 119 into your workbook.
- Test various areas of the skin for sensitivity. Sometimes touch the area

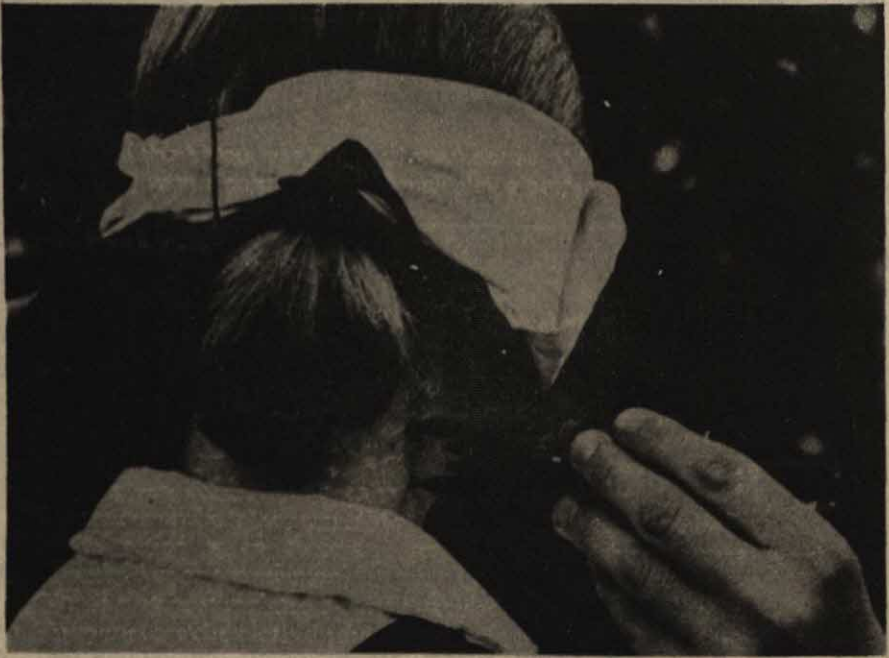


Figure 10.12

being tested with one point, and at other times with the two-pencil arrangement. Make sure, when testing with two pencils, that the two points make contact with the skin at the same time. Carry out the tests in a random fashion.

- Each time you make a test ask your partner if he or she feels one or two pencils.
- Record the responses by placing a tick in the table for a correct response and a cross for a mistake.

Area tested	Response	
	"One point"	"Two points"
fingertip		
palm of hand		
back of hand		
back of neck		
chin		
lip		
tongue		
arm		
forehead		
calf of leg		

Question

10.2 Write a conclusion stating which are the more sensitive areas of your skin and which the less sensitive.

EXPERIMENT

10.3

What is the most sensitive area of your tongue?

Each pair will need:

- glass rod with smooth ends
- 10 per cent salt solution (10 g per 100 mL)
- 10 per cent sugar solution

What to do

- Draw a large outline of the shape of the tongue.
- Blindfold your partner.
- Ask your partner to poke out his or her tongue.
- Using the glass rod, place a drop of one solution on a spot on the tongue. Ask your partner to identify the solution. If the answer is correct, place a tick on the drawing of the tongue in the area tested. If wrong, place a cross.
- Test different areas of the tongue in the same way, rinsing out the mouth and washing the glass rod after each test.

Question

10.3 What are the more sensitive areas of the tongue? Mark them on your diagram.

EXPERIMENT

10.4

Why does food seem tasteless when you have a cold?

Each pair will need:

- finely chopped banana, apple, onion, orange, lemon and cooked potato
- bread
- plastic clothes peg

What to do

- Mix a little of each food with bread. This is done to hide the texture of the food.
- Blindfold your partner and place a clothes peg on his nose.
- Give your partner a small sample of one of the foods mixed with bread, asking him to identify it by tasting it.
- Record your results in a copy of the table below. Place a tick for a quick recognition and a cross for a slow recognition or a wrong result.
- Rinse out the mouth and repeat the test using another food. Sometimes you should give your partner a sample of a food that has already been tested. This reduces the chance of successful guessing as you come to the end of the list.
- Repeat the whole experiment with the nose unpegged.

Food tasted	Response	
	With nose pegged	With nose unpegged

Question

10.4 Do you think you lose some of your sense of taste when your nose is blocked with a cold? Or does smell play a part in "tasting" food?

Coordination

- Nerves conduct impulses to and from the central nervous system.
- Nerves are made up of nerve cells called neurones.
- Each neurone has
  - a cell body
  - nerve fibres called axons and dendrites.
- Impulses travel one way along a neurone:
  dendrite → cell body → axon.
- Neurones may be (a) sensory, (b) motor, or (c) connecting neurones.
- Reflex action is an automatic response in which the spinal cord "decides" upon the reaction.
- Glands may be stimulated by nerve impulses to secrete hormones.
- Hormones are chemicals discharged into the bloodstream by glands.
- Certain organs of the body respond to certain hormones.

Spelling list

adrenalin
autonomic
axon
cerebellum
cerebrum
coordination
cortex
dendrite
diabetes
insulin
medulla
nervous
neurone
ovaries
pancreas
perception
pituitary
receptor
reflex
salivation
spinal
stimulant
stimulus
system
testes
thyroid
thyroxin
voluntary

Things to do

10.5 Refer to library books to find some optical illusions not mentioned in this chapter. Magicians often make use of optical illusions. Do you know of any magicians' tricks of this kind?

10.6 Estimate the average reaction time of a group of people. Arrange the group in a circle, each person holding the hand of the person on either side of him. One of the group holds a stop watch in his right hand. He starts the watch and at the same time squeezes the hand of the person on his left. This person then squeezes the hand on his left, and so on around the circle. The last person squeezes the wrist of the watch-holder and he stops the watch. The average reaction time is the total time divided by the number of people in the circle.

10.7 What is "persistence" of vision? What part does it play in our being able to enjoy movies and television?

10.8 What is the nearest object on which you can focus clearly? Test one eye at a time by holding a pin at arm's length and then moving it closer until you cannot see it clearly. Measure the distance in centimetres. Test the eyes of your parents in the same way. What do you find?

10.9 Look closely at a well-illuminated red object for about 30 seconds. Then face a white wall and close your eyes. What do you see? Test other colours. Compare your results with the results of other members of your group. The effect is called "after-image". Try to find an explanation for it.

10.10 A full moon just rising appears much larger than the same moon high in the sky. Why?

10.11 How well can you tell the direction from which a sound is coming? Ask your partner to blindfold you, then tap two pencils together about a metre away in various positions around your head. Point in the direction from which you think the sound is coming.

10.12 Examine a prepared slide of a cross-section of the spinal cord of a rabbit. Can you distinguish between white and grey matter in the spine?

More questions

10.13 Name five receptors.

10.14 Draw a typical nerve cell. Label the dendrites, the cell body and the axon and show the direction in which impulses travel through the cell.

10.15 What is a reflex arc? Do you think that catching a ball in slips in cricket is a reflex action? (The slips fieldsmen stand close to the batsman.) Explain your answer.

10.16 In the introduction to this chapter three examples of coordination are given. In each of these examples name the stimulus, the response, the receptor and the effector.

10.17 Some people are said to have plenty of "grey matter". What does this saying mean? How did it come about?

10.18 The human brain is superior to that of any other animal. In what respect would you expect the brain of a bird to differ from the brain of a human? (R)

10.19 Compare the functions of motor neurones and sensory neurones. How do they differ in construction?

10.20 What are hormones? Name two. Give the names of the glands that secrete each of these hormones and locate the area of the body in which each of these glands is situated.

10.21 Imagine you are being charged by a bull in a paddock. You turn, run to a high fence and dive over out of harm's way. Give a brief account of the coordination occurring in your body during this emergency.

10.22 Is diabetes a fatal condition? How is a patient with this disease treated? (R)

10.23 What part of the body is attacked by the disease poliomyelitis? (R)

Test yourself (chapter 10)

Write the answers to questions 1 and 2 in your workbook.

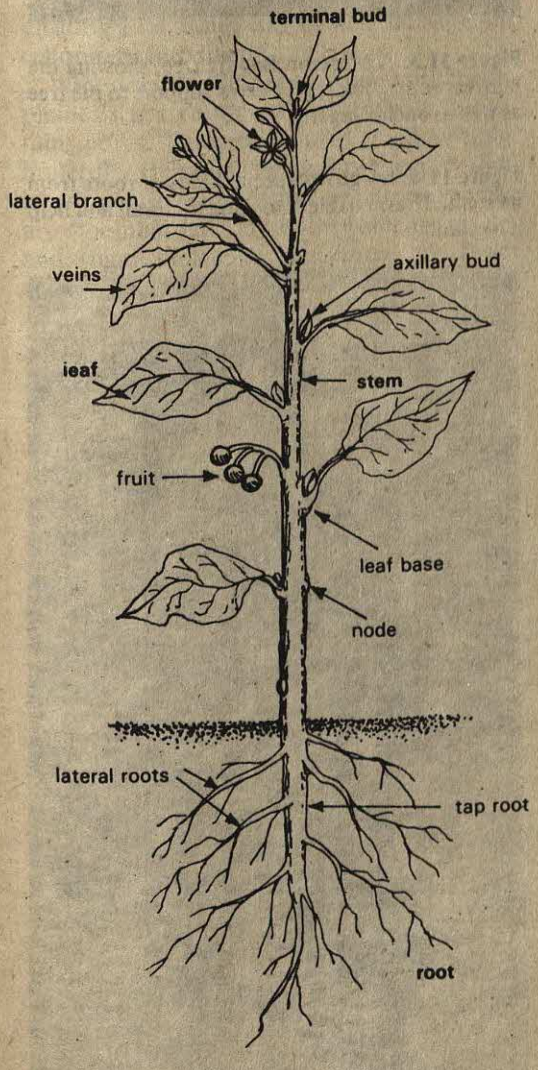
1. Is there any difference between a nerve and a neurone? If so, what is it?
2. A girl sees an orange and reaches out to pick it up. Which of the following events take place in her body when this happens?
   - (a) A nerve impulse travels from her brain to muscles in her arm.
   - (b) A nerve impulse travels from her fingers across her spine and back down her arm to muscles there.
   - (c) Some muscles in her arm contract.
   - (d) Nerve impulses travel from her brain to her eye.
   - (e) Nerve impulses travel from her arm muscles to her brain.
   - (f) Nerve impulses travel from the retina of her eye to her brain.

In each of the following questions, write down the words that best complete the sentences.

3. A motor neurone has a long (a) _______ and a short (b) _______.
4. The beating of the heart, breathing, digestion, etc., are controlled by that part of the brain called the _______.
5. The part of the brain concerned with thinking is called the _______.
6. A person accidentally touches a hot stove and immediately pulls away her hand. This is called a (a) _______ action. It happens because a nerve impulse travels along a (b) _______ through to the (c) _______ and thence to a (d) _______.
7. The amount of glucose in the blood is controlled by the (a) _______. The hormone secreted by this gland is (b) _______.
8. The (a) _______ gland controls growth and is located at the (b) _______.

11

The flowering plant: how it works



Most of the plants we know bear flowers. Think of the rose, the peach tree, the bottlebrush, couch grass, the carrot, bean and pumpkin, the eucalypts and wattles.

However, it must be remembered that there are some plants that do not have flowers, for example, the mosses, ferns and conifers. These other classes of plants are examined in chapter 20. For the moment we shall confine our attention to only the one class, the flowering plants.

Organs of a plant

In the same way as your body has organs, such as the heart, lungs, liver and eyes, the body of a plant has organs. These are the root, stem, leaf, bud and flower. (Refer to figure 11.1.)

Roots

The root system of a plant may consist of a single taproot with numerous lateral roots branching off it. This type is shown in figure 11.1. Other plants have a bunch of roots

Figure 11.1: Diagram showing the parts of a flowering plant. The organs of the plant are the root, stem, leaf, bud and flower. The flower gives rise to fruit, which contain the seeds. The angle between the stem and a leaf is called the axil. The axil contains an axillary bud that may develop into a branch.

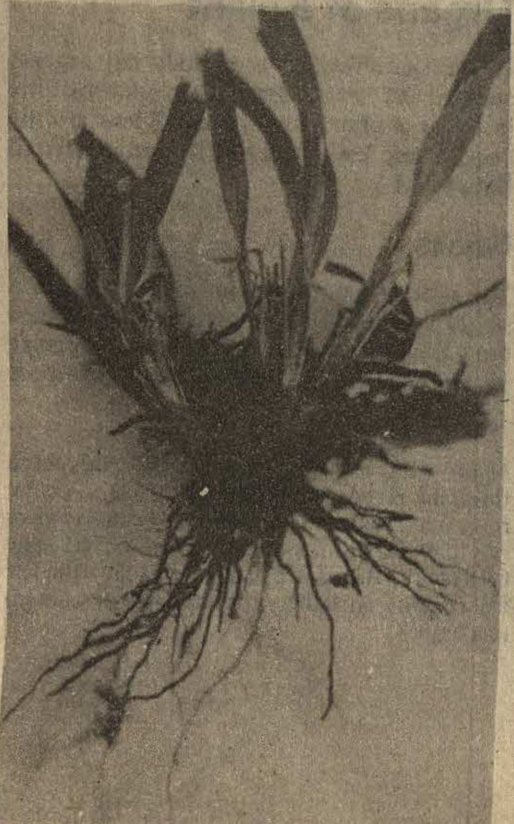
spreading out from the base of the stem. All grasses are of this type. (See figure 11.2.)

Some taproots store excess food — mainly in the form of starch. The carrot is an example. The carrot plant has a life cycle of two years. In the first year it grows leaves and produces the root. No flowers are formed. In winter the leaves wither and die. Next spring the carrot grows new leaves and, finally, flowers and seeds. Much of the food for this second growth comes from the root, which explains why carrots shrivel if left in the ground more than a year.

Roots anchor the plant

Look at figure 11.2. The total length of the root system is many times the length of the stem. It is difficult to pull a grass plant out of the soil — it is firmly anchored by its roots. When you do pull it up, a lot of soil comes with it. Roots bind the soil together and so help to prevent erosion.

Figure 11.2: A clump of paspalum roots. All grasses have a fibrous root system that spreads out in a clump from the base of the stem. There is no taproot.



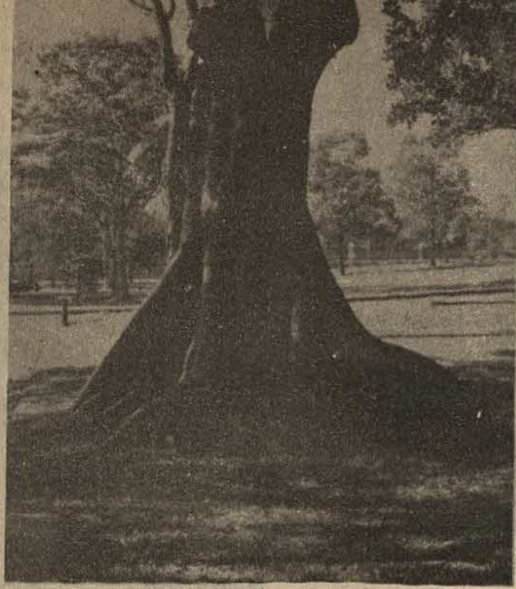
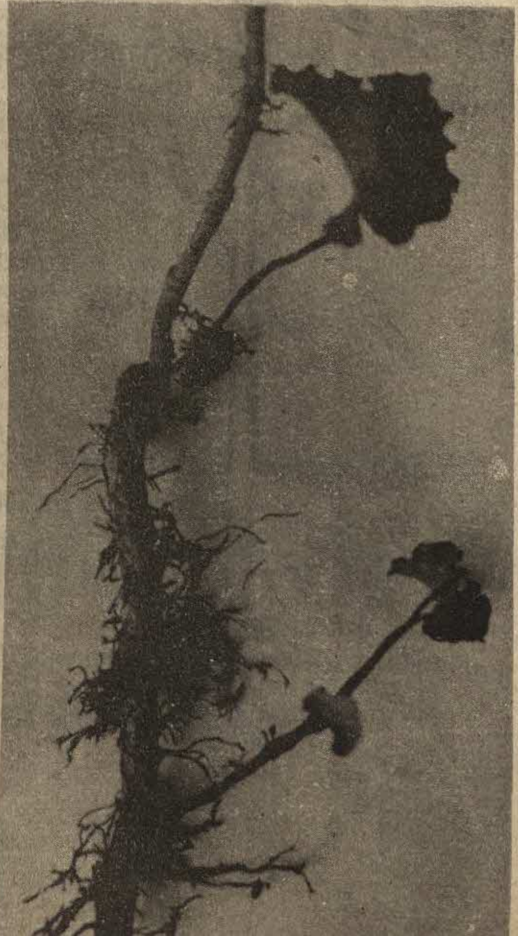


Figure 11.3: A Moreton Bay fig tree, showing the buttress roots. These give extra support to the tree as well as anchoring it.

Figure 11.4: Ivy grows special kinds of roots from its stem. These enable it to cling to a wall and help it to climb.



Roots absorb water and salts

If the soil around a plant is not watered, the plant withers and eventually dies. Obviously the plant gets its water through its roots.

Water is absorbed mainly by a process called *osmosis*. An experiment illustrating osmosis is shown in figure 11.5. This experiment uses a piece of coloured cellophane gathered in the form of a loose pouch. The pouch contains concentrated sugar solution and is fastened at the top with a rubber band. It is placed in a jar containing dilute sugar solution. After an hour or so it will be noticed that the pouch has swollen, indicating that water has passed through the cellophane into the bag.

Why does this happen? Apparently cellophane is not completely watertight; it contains pores. These pores tend to allow small molecules to pass through more readily than large ones. The inside and outside of the bag are "bombarded" by both water molecules and sugar molecules, but there are fewer sugar molecules outside than inside. Therefore, the outside is struck more frequently by water molecules than the inside is. Being smaller than sugar molecules they tend to pass through more readily. Thus the bag slowly gains water and the pressure inside builds up.

Osmosis may be demonstrated in another way. If a limp celery stalk is immersed in water it soon becomes crisp. The cells of the celery plant contain sap that is a solution of molecules and ions needed by the plant to grow. With pure water on the outside, water molecules tend to pass into the stalk rather than leave it. The extra water in the cells makes the celery crisp.

The reverse will happen if a stalk is placed in a strong salt solution — it soon becomes limp. (See figure 11.6.)

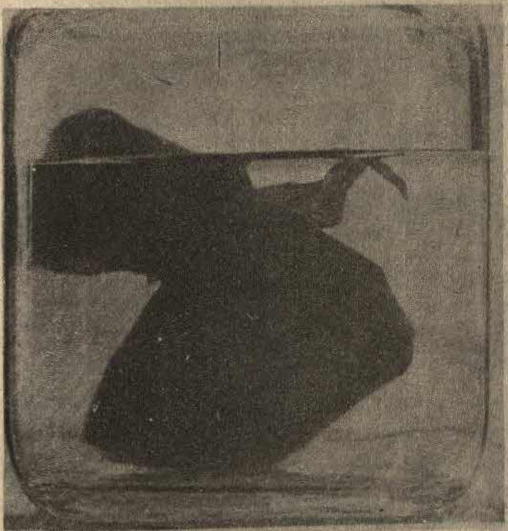


Figure 11.5: Demonstrating osmosis. The cellophane bag contains a concentrated sugar solution. It is immersed in a dilute sugar solution. Because of the different amounts of sugar inside and outside the bag, water diffuses more rapidly into the bag than out of it.

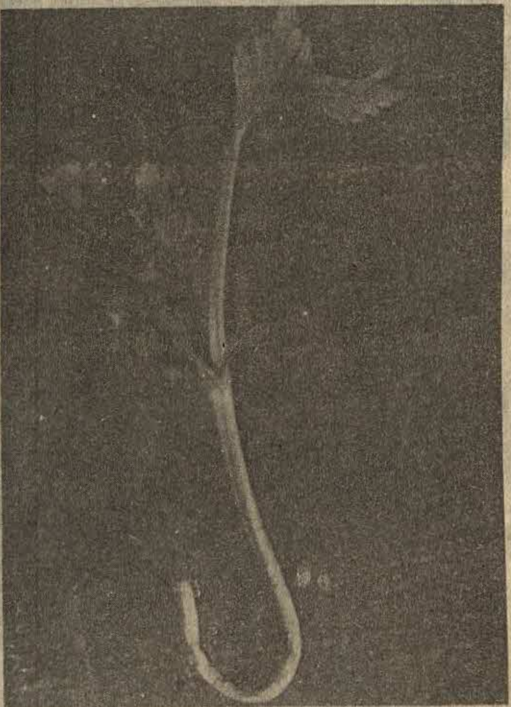


Figure 11.6: A celery stalk that has been standing in a strong salt solution for a couple of hours. The solution surrounding the stalk was more concentrated than the sap in the cells of the stalk. Therefore water passed from inside the cells to the solution outside.

Root hairs

The root system of a plant contains a multitude of root hairs. These are not usually noticed because they are torn away when a plant is lifted out of the soil, no matter how carefully it is lifted. Figure 11.7 is a photo of a young radish seedling that has been allowed to germinate on moist blotting paper.

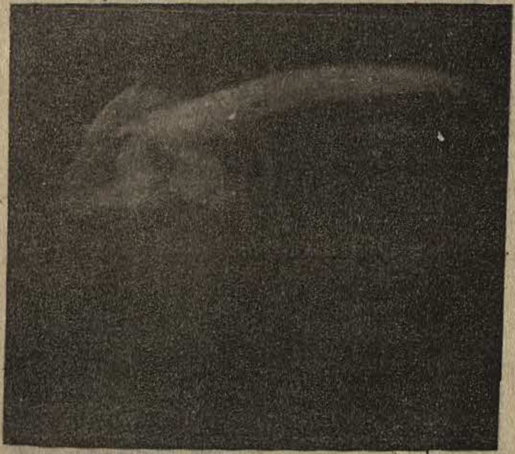


Figure 11.7: A germinating radish. Notice the root hairs on the main root.

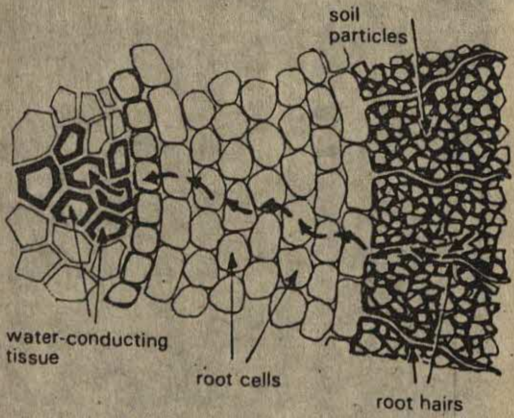


Figure 11.8: A cross-section through a small root. It shows the root hairs threading through the soil. These are long single cells that absorb the water and salts needed by the plant. The water passes from the root hairs through the intervening root cells to the water-conducting tubes. These transport the water to all parts of the plant.

It is the root hairs that absorb the water. Each root hair is a single long cell. It threads its way through particles of soil and absorbs water through the cell membrane by osmosis. It does this because the concentration of substances in the sap of the root is greater than the concentration of substances dissolved in the soil water. When the root hair is swollen with water its sap is more dilute than is the sap in the adjoining cells. Consequently, water tends to pass into the next cell by the same process, and so on until it reaches the "arteries" of the plant. These are the water-conducting tissues near the centre of the root. (See figure 11.8.) They are long tube-like cells with their end walls perforated, giving them the structure of pipes.

Roots absorb mineral salts

So far we have discussed only the absorption of water by the plant. But a plant needs mineral salts as well as water for growth. (See figure 11.9.) The quantity of salts required is minute. Mineral salts exist in the water as ions. Three examples are

- the potassium ion, K^+

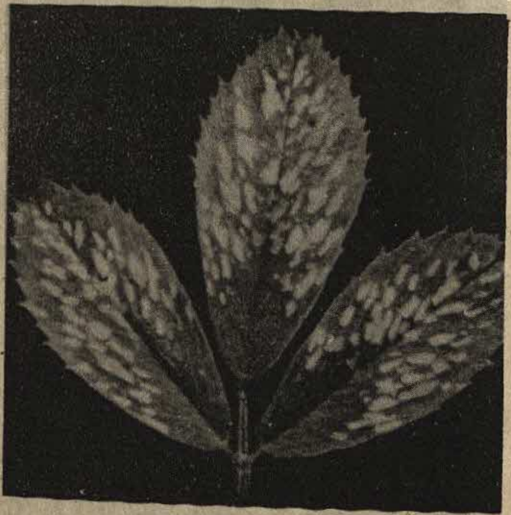


Figure 11.9: Plants need salts. This photograpn shows the effect of potassium deficiency on a lucerne leaf, resulting in a speckled appearance. (Photo courtesy Queensland Department of Primary Industries)

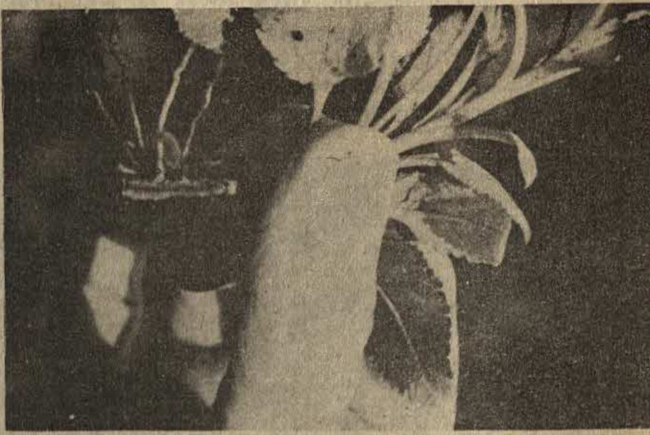
- the phosphate ion, PO_4^{3-}
- the nitrate ion, NO_3^-

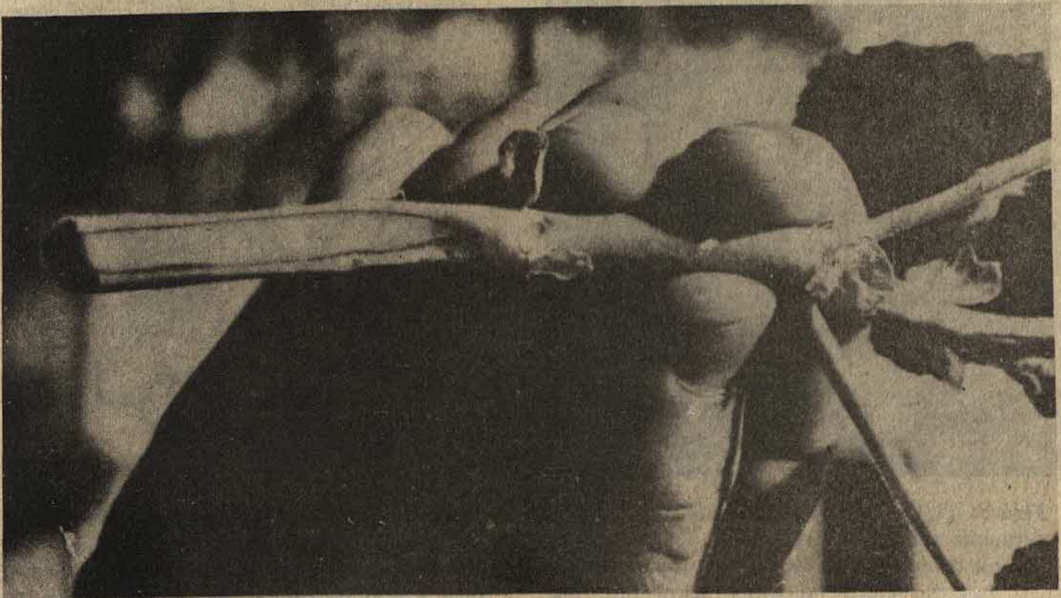
Even though they are larger than water molecules, the occasional ion passes through the membrane of the root hairs in the same way as water does. If the concentration of ions in the soil water is too great, water tends to pass out of the roots instead of into them and the plant eventually dies.

Stems

The stem of a plant does two important things. It conducts food and water to the various parts and it gives support to the leaves, flowers and fruits.

The way in which water is conducted through the stem may be demonstrated by digging up a plant, carefully washing away excess soil, and immersing the roots and remaining soil in a solution of red ink or eosin. When the red colour can be seen in the leaves, the plant is removed from the ink. Sections are then cut across and along the stem and also across the main root. Figure 11.10 shows the result of this investigation. From this figure we can see that water-conducting vessels are in one bundle in the centre of roots and in separate bundles around the stem. These water-conducting vessels are called *xylem* tubes.





Figures 11.10A (top) and B (bottom): The xylem tubes in roots and stem. Both cuttings have been in red ink for several days. In B, notice the red stain at the edge of the stem. In A, the red stain is near the centre of the root.

It is not as easy to find the food-conducting tubes in the stem. Figure 11.11 illustrates an experiment that shows that these are also in the outer tissues. Food-conducting tissues are called *phloem* tissues.

Many plants are annuals — they die as winter approaches However, perennials, like the rose, merely become inactive. In perennials the xylem tubes die and form a woody ring called a growth ring; new conducting tissue is formed next spring near the surface of the stem. The plant thus grows outwards in girth.

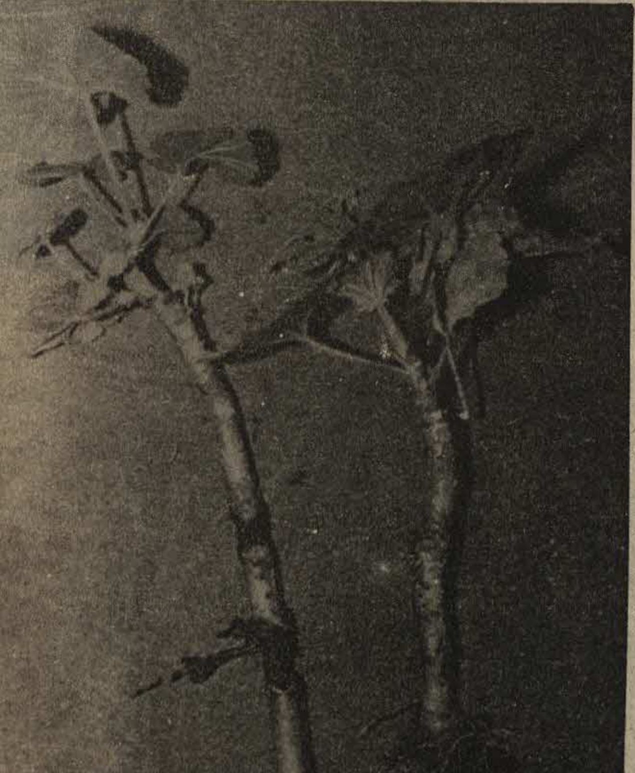


Figure 11.11: Showing two stems from a geranium plant that have been in the same potting soil for several weeks. Notice that the one on the left has developed no roots below the ring-barking. This is because the stem has been unable to pass down food to form them. The experiment indicates that food travels in the outer layers of the stem.

Leaves

So far in this chapter we have discussed the absorption of water by the roots of a plant and its conduction through the stem. We now try to find out what happens to this water in the leaves. Before we can do this we must understand the structure of a leaf.

Choose a broad-leafed plant such as a privet. Tear off a piece of the leaf and look at the exposed cross-section with a hand lens. Notice that there is a yellowish skin top and bottom, and that the inside of the leaf is a dark green. As you tear across the leaf you may expose a small strip of the bottom skin, particularly near a vein. Mount a piece of this skin in a drop of water under a cover slip on a microscope slide. Examine with a microscope, using first the low power and then the high power objective. Figure 11.12 is a drawing of what you may expect to see.

This drawing shows the stomates and guard cells. The leaf "breathes" in and out

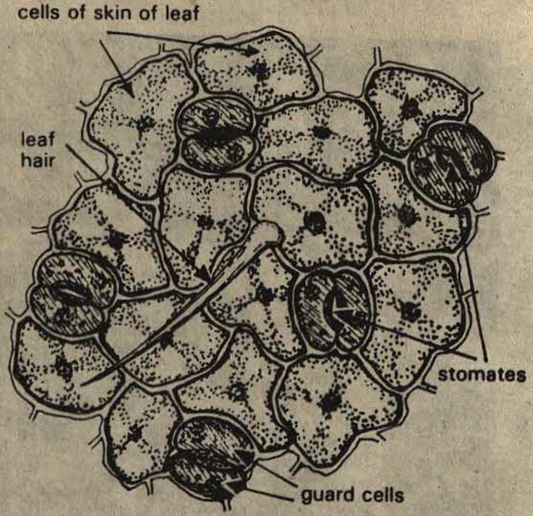


Figure 11.12: A piece of the underneath skin of a leaf. Notice the openings called stomates. Each stomate has a pair of guard cells. When the plant's cells are full of water and swollen, the stomates are open. When the plant is short of water, its cells shrink and the leaf wilts. Shrinkage of the guard cells closes the stomates and helps reduce further loss of water.

through the stomates; the guard cells protect the plant during dry weather. A shortage of water causes the plant cells to shrink and the leaves to droop. A shrinkage of the guard cells closes the stomates, which stops further loss of water by evaporation.

Figure 11.13 is a magnified cross-section of a leaf. Your school may have a prepared slide that you can examine to observe these structures for yourself. To prepare such a slide yourself you will need to pile about twenty leaves one on top of the other, and cut thin slices through the leaves with a razor blade.

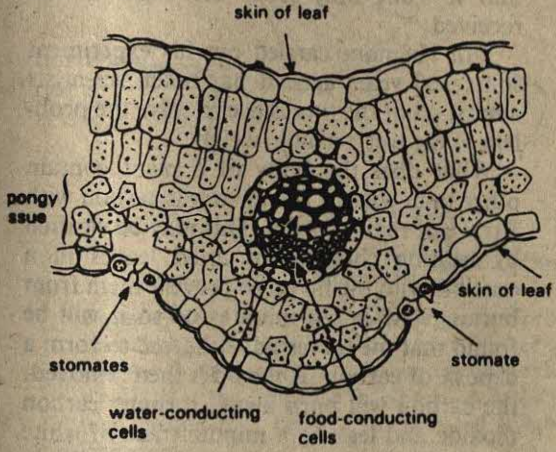


Figure 11.13: A magnified cross-section of a leaf. Notice the large number of air spaces in the spongy tissue. These spaces may be regarded as the "lungs" of the leaf. They allow excess water vapour and oxygen to leave the plant and carbon dioxide to be absorbed.

Notice the air spaces within the leaf. These spaces are where the exchange of gases takes place — water vapour and oxygen are given out and carbon dioxide is taken in.

Transpiration

Figure 11.14 illustrates an experiment set up to verify that water vapour is given off from the under-surface of leaves. This process is called transpiration. The water is absorbed through the roots, rises through the stem and escapes through the leaves. Minute quantities of mineral salts are in solution in the water and these are extracted as the water passes through the cells.

Why does water rise through the stem or trunk of a plant? In some plants, such as eucalypts, the stem can be as tall as 75 metres. The water cannot rise because of air pressure, because the stomates in the leaves at the top of the plant are generally open.

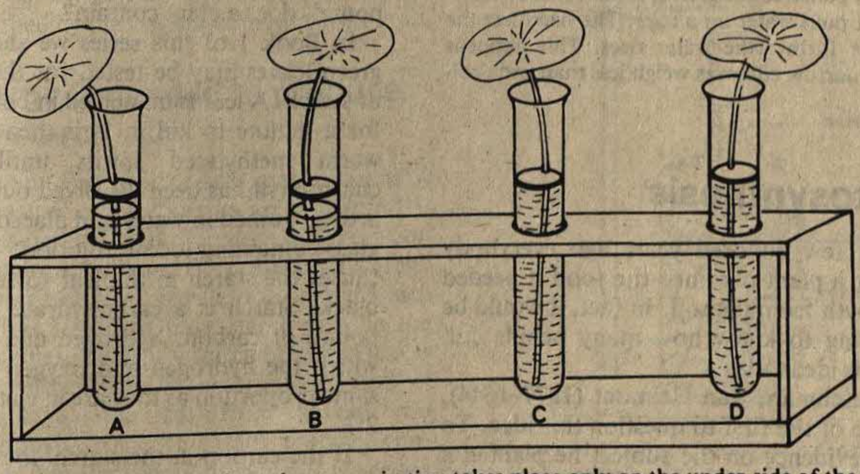


Figure 11.14: An experiment to show that transpiration takes place only on the under-side of the leaf. The water in each tube is covered with wax to prevent evaporation. Leaf A has no Vaseline on it. Leaf B has it on the top only. Leaf C has it on the under-side only and leaf D has it on both sides. The water level drops equal amounts in tubes A and B. The level does not drop in C and D.

Even if this were not so, the maximum height to which air pressure can push water is only 10 metres — and only if there is a sealed vacuum at the top.

Water rises in the stem of a plant by a process called *capillarity*. It is the same process that causes ink to be soaked upwards in blotting paper. Figure 11.15 attempts to explain capillarity. Water adheres to the glass and it is this force of adhesion that pulls the water upwards. The narrower the glass tube, the further the water will rise in it. This happens because a narrow column of water weighs less than a wide one. The conducting tubes in the stem of a plant are extremely narrow. It is this narrowness that pulls the water up the plant.

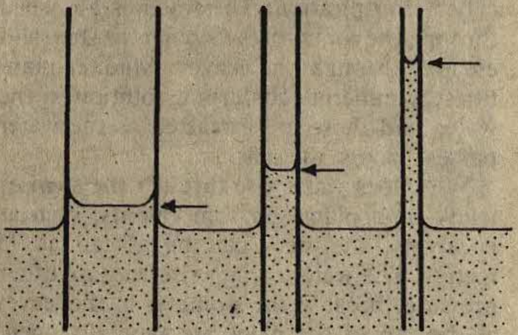


Figure 11.15: Capillarity. Water adheres to glass, that is, is pulled towards it. It is this force of adhesion that pulls water up a tube. The narrower the tube, the further the water rises. This happens because narrow columns weigh less than wide columns.

Photosynthesis

Until a few hundred years ago everybody thought a plant obtained the food it needed for growth from the soil. In fact, it would be interesting to know how many people still have this idea today.

A Dutchman, Van Helmont (1577-1644), was one of the first to question this idea. To obtain evidence on the subject he planted a young tree in a tub of soil. He tended it for five years and found at the end of that period that it had gained 75 kilograms in weight but that its soil had lost only 50 grams. Van Helmont concluded that the tree's gain in weight must have come solely from the water it had received and not from the soil.

Van Helmont was right when he said that the increase in weight did not come from the soil. He was wrong, however, when he said that it came only from the water it had received.

Van Helmont carried out his experiment some 300 years ago. It has taken scientists almost all of the time since to solve the problem of the tree's gain in weight.

What does the body of a plant contain other than water? The answer is carbon with a trace of mineral salts. This may be verified by heating chopped-up dried leaves in a crucible with the lid on to prevent them from burning. After ten minutes or so it will be found that the leaves have charred to form a deposit of carbon. If the lid is then removed, the carbon will burn away, forming carbon dioxide and leaving a minute trace of white solids. These solids are the mineral salts in the plant.

Leaves contain starch

Let us now find out how the carbon is held in the plant. In other words, what carbon compounds does a plant contain?

In Book 1 of this series we showed how green leaves may be tested for the presence of starch. A leaf is immersed in boiling water for a minute to kill it. It is then soaked in warm methylated spirits until all the chlorophyll has been dissolved out. The leaf is then washed in water and placed in a clock glass containing iodine solution. The iodine causes the starch in the leaf to turn bluish-black. Starch is a carbohydrate — a compound of carbon, hydrogen and oxygen in which the hydrogen and oxygen are in the same proportion as they are in water, namely 2:1.

If the carbon in the starch does not come from the soil, then it must come from the air. The substance in air containing carbon is carbon dioxide.

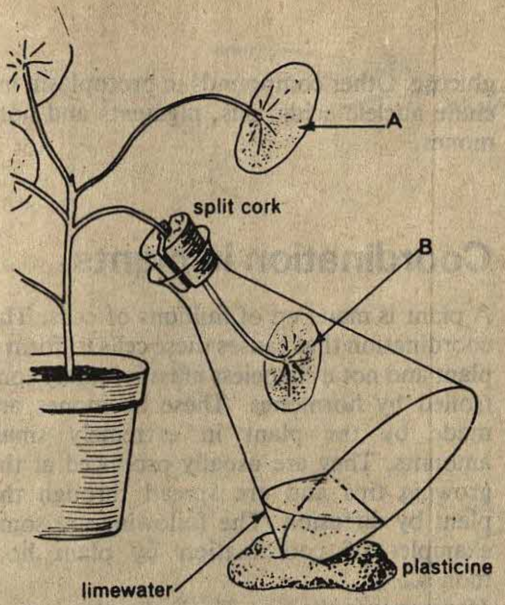


Figure 11.16: Carbon dioxide is necessary for the formation of starch in leaves. Starch is formed in leaf A, which is exposed to carbon dioxide in the air. Starch is not formed in leaf B because any carbon dioxide near the leaf is absorbed by the limewater.

Can we show that carbon dioxide from the air is actually used to make the starch? Figure 11.16 illustrates an experiment that does this. No starch is formed in leaf B because any carbon dioxide near the leaf is absorbed by the limewater in the flask.

Energy is needed to produce the starch

Have you ever noticed how grass covered by a board or stone loses its green colour? Is there any relationship between this green colour (chlorophyll) and the presence of starch? A variegated leaf provides the answer. Such a leaf is found to have starch only in the green parts. Evidently starch occurs in leaves only where there is chlorophyll. And if sunlight is shut off from a leaf, no chlorophyll forms. This leads us to the conclusion that the energy of sunlight is needed to produce starch in leaves. The reaction that produces the starch may therefore be described as a photosynthetic one ("photo" = light).

We have shown that starch is produced in leaves as a result of photosynthesis. But it should be understood that starch is not the direct product of photosynthesis. The substance actually formed in photosynthesis is glucose; this is then changed to starch in the plant.

Glucose is a simple sugar and, like starch, is also a carbohydrate. The following is a simplified equation representing the formation of glucose from carbon dioxide and water. (For further information on this reaction, see appendix 1.)

$$\text{carbon dioxide} + \text{water} + \text{light energy} \xrightarrow{\text{chlorophyll}} \text{glucose} + \text{oxygen}$$

$$6CO_2 + 6H_2O + \text{energy} \longrightarrow C_6H_{12}O_6 + 6O_2\uparrow$$

This equation shows that oxygen is formed as well as glucose. How can we show in an experiment that photosynthesis produces oxygen?

Green leaves produce oxygen

Figure 11.17 shows an experiment that demonstrates that green leaves produce oxygen. The elodea under the funnel must be ex-

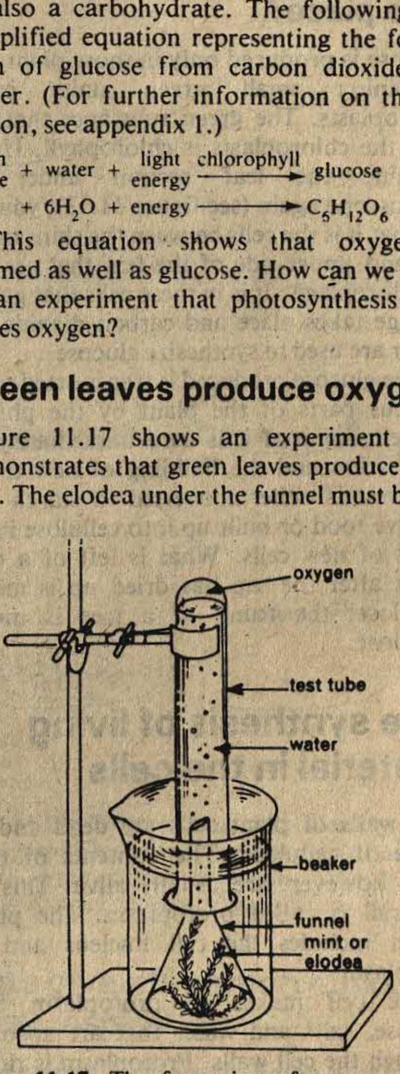


Figure 11.17: The formation of oxygen during photosynthesis. A better yield of oxygen is obtained if the water in the beaker is first saturated with carbon dioxide.

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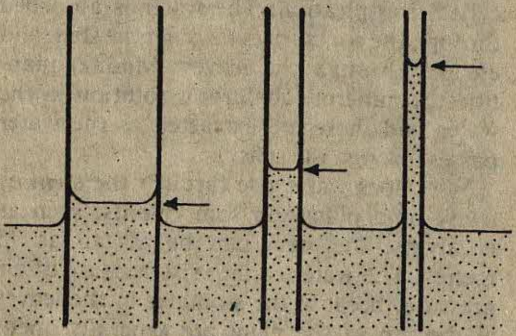

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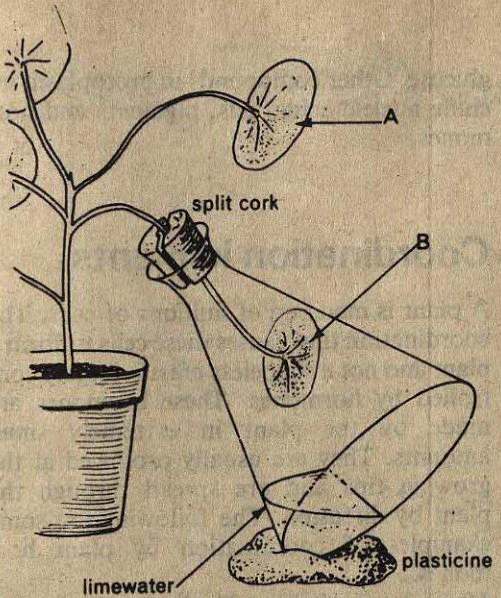

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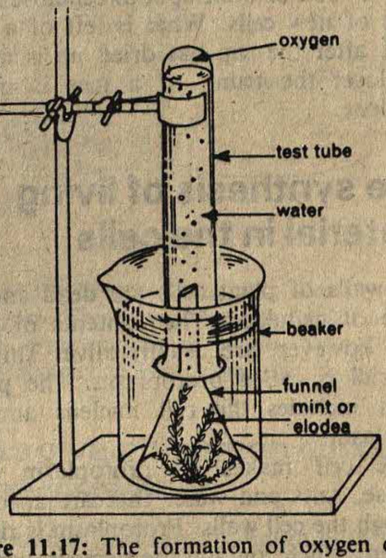


Figure 11.17: The formation of oxygen during photosynthesis. A better yield of oxygen is obtained if the water in the beaker is first saturated with carbon dioxide.

posed to sunlight. The experiment works better if the water is warm and if it is first saturated with carbon dioxide. When sufficient gas has been collected at the top of the test tube, it is tested with a glowing splint. The splint lights up, indicating the gas is oxygen.

Where does photosynthesis take place?

Glucose is produced only in those plant cells containing small green units called chloroplasts. The green substance that colours the chloroplasts is chlorophyll. If you examine the leaf section under the microscope again (see figure 11.13), you will see that it is the cells between the skins on the top and under-side of the leaf that are rich in chloroplasts. It is in these cells that gas exchange takes place and carbon dioxide and water are used to synthesize glucose.

The glucose produced is transported to the various parts of the plant by the phloem tissues. Some of it is used immediately for respiration and the building of new tissue. The rest is either converted to starch as a reserve food or built up into cellulose in the walls of new cells. What is left of a dead plant after the sap has dried up is mostly cellulose; the trunk of a tree is mostly cellulose.

The synthesis of living material in the cells

The walls of plant cells are dead and are made of cellulose. The contents of these cells, however, are usually alive. This live material is called protoplasm. The protoplasm includes the cell nucleus and the cytoplasm.

The cell makes its protoplasm from glucose, salts and water that are absorbed through the cell walls. Protoplasm is rich in protein, which contains the elements carbon, hydrogen, oxygen and nitrogen. The nitrogen is derived from salts that the cell absorbs. The other elements come from the glucose. Other compounds in protoplasm include nucleic acids, oils, pigments and hormones.

Coordination in plants

A plant is made up of millions of cells. The coordination that causes these cells to form a plant and not a shapeless mass is largely controlled by hormones. These hormones are made by the plant in extremely small amounts. They are usually produced at the growing tips and are spread through the plant by diffusion. The following are some examples of coordination by plant hormones.

Hormones in the bud. The bud at the apex of a shoot secretes a hormone that inhibits growth at the other buds. If this bud at the apex is removed other buds begin to grow. This explains why a hedge that is trimmed regularly becomes very bushy.

Hormones in young leaves. Hormones are produced in young leaves. These hormones stimulate the formation of roots. They also stimulate the production of new xylem tissue. Thus an added supply of water and dissolved salts can be brought to the new leaves.

Respiration

Plant respiration is much the same as animal respiration. Glucose combines with oxygen to liberate energy and form carbon dioxide and water.

$$\text{glucose} + \text{oxygen} \rightarrow \text{water} + \begin{matrix}\text{carbon}\\ \text{dioxide}\end{matrix} + \text{energy}$$

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + \text{energy}$$

The glucose in the plant comes either directly from photosynthesis or from the starch that has been stored in the cells. The energy from respiration is used to manufacture all the substances needed by the plant to make new cells and to keep old ones working.

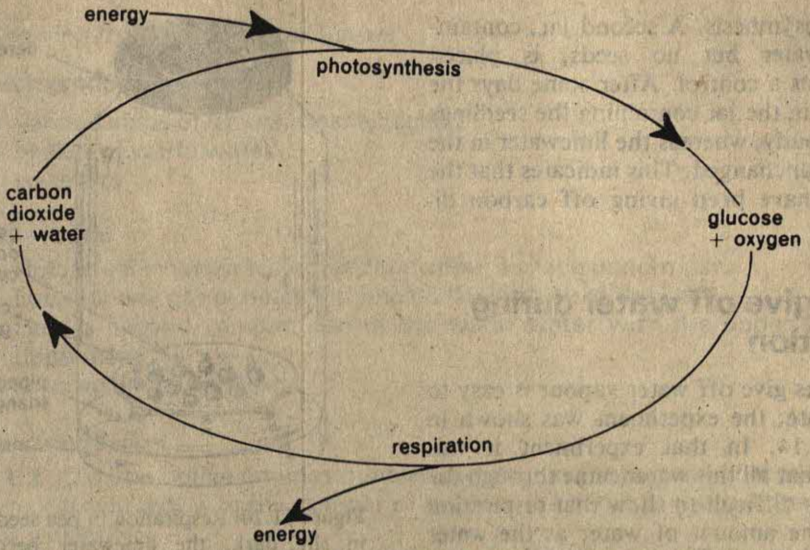


Figure 11.18: Photosynthesis and respiration form a cycle. Photosynthesis absorbs energy; respiration releases it.

Respiration and photosynthesis form a cycle. Respiration releases energy; photosynthesis absorbs it from the sun. (See figure 11.18.)

Photosynthesis and respiration take place in a plant at the same time, provided the plant is in sunlight. Photosynthesis takes in carbon dioxide and water; respiration gives out carbon dioxide and water.

Plants absorb oxygen in respiration

That plants absorb oxygen in respiration may be demonstrated by placing a number of pea seedlings on damp cottonwool in a jar. (See figure 11.19.) The jar is placed in the dark to stop photosynthesis. The young plants obtain their food from the seeds. After three or four days a lighted taper placed in the jar does not burn nearly as well as in a second similar jar that contains no seedlings. This experiment gives some evidence that growing seedlings absorb oxygen.

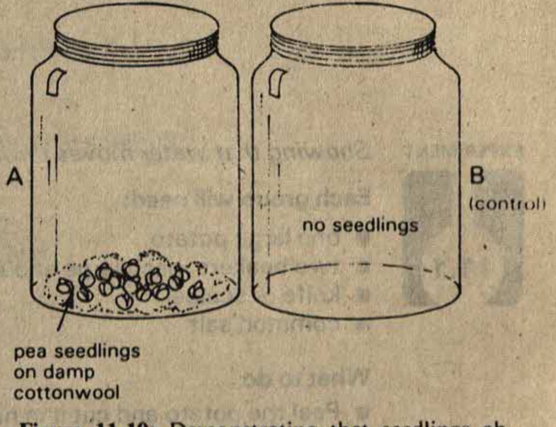


Figure 11.19: Demonstrating that seedlings absorb oxygen. This experiment was carried out in the dark to prevent photosynthesis. After several days, jar A contained less oxygen than jar B.

Plants give off carbon dioxide during respiration

The apparatus illustrated in figure 11.20 may be used to demonstrate that seedlings give off carbon dioxide as they grow. The jar is placed in the dark for three or four days to stop photosynthesis. A second jar, containing limewater but no seeds, is placed alongside as a control. After some days the limewater in the jar containing the seedlings is quite cloudy, whereas the limewater in the control is unchanged. This indicates that the seedlings have been giving off carbon dioxide.

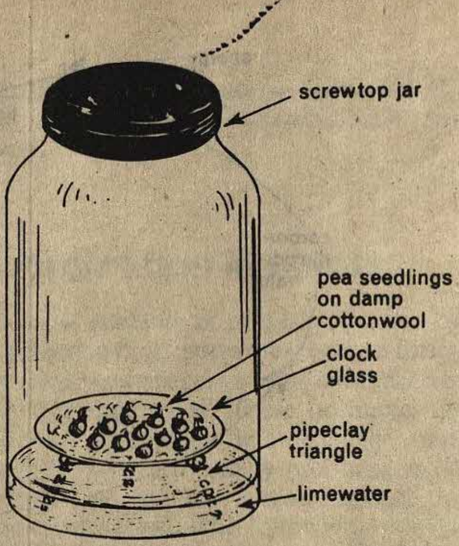


Figure 11.20: Respiration in pea seedlings. Placed in the dark, the limewater becomes cloudy because of carbon dioxide given off. The limewater in a second jar without seedlings does not change.

Plants give off water during respiration

That plants give off water vapour is easy to demonstrate; the experiment was shown in figure 11.14. In that experiment it was assumed that all this water came through the roots. It is difficult to show that respiration adds to the amount of water as the water travels up the stems and out through the leaves. Of course, some of the water is absorbed in the manufacture of glucose.

EXPERIMENT *Showing that water moves through root cells*

11.1

Each group will need:

- one large potato
- two beakers, each large enough to just hold the potato
- knife or scalpel
- common salt

What to do

- Peel the potato and cut it in halves.
- Hollow out each half, making sure that when you finish you have a thin continuous shell of potato tissue.
- Prepare about 250 mL of concentrated salt solution.
- Put a little salt solution in one half of the potato and float it in tap-water in a beaker.
- Put tap-water in the other potato half and float it in salt solution in the second beaker.
- Leave the beakers for an hour or so, then look at the two potato halves again.

Question

11.1 Describe what happened and explain how it occurred.

EXPERIMENT 11.2

Showing that leaves give off gases

Each group will need:

- various kinds of leaves, freshly picked
- beaker of warm water
- tweezers

What to do

- Hold a leaf in warm water with the upper surface uppermost.
- Look for any gas bubbles forming on the surface of the leaf.
- Hold a second, similar, leaf in the warm water with the under-surface uppermost.
- Look again for bubbles.

Questions

11.2 Did you notice any gas bubbles forming on the surface of the leaves? If you did, was the number of bubbles the same for both sides of the leaf?

11.3 Did the bubbles expand as they formed on the leaf? Can you explain why?

11.4 Write a conclusion from your observations.

EXPERIMENT 11.3

Making a leaf produce your initials on its surface

Each group will need:

- a geranium or similar plant in a pot or in a garden
- piece of cardboard
- four paper clips
- beaker of warm methylated spirits
- second beaker in which to boil water
- tripod
- gauze
- Bunsen burner
- scalpel or razor blade
- clock glass
- iodine solution

What to do

- Select a green leaf, but do not remove it from the stem.
- Cut two pieces of cardboard, both the same size and each big enough to cover the leaf selected.
- Cut your initials in wide letters on one of the cardboard pieces.
- Clip the two pieces of cardboard together so that the leaf is sandwiched between them with your initials uppermost.
- Place the plant in sunlight.
- After 24 hours, pick the leaf and kill it by placing it in boiling water. Remove the chlorophyll, wash the leaf and add iodine solution to develop your print.

EXPERIMENT

11.4

What colours are present in the leaf of a plant?

Each group will need:

- several fresh leaves of geranium, nasturtium or spinach
- 100 mL measuring cylinder
- strip of clean blotting paper about 2 cm wide and as long as the measuring cylinder
- scalpel
- mortar and pestle
- a little clean sand
- methylated spirits
- glass rod
- sticky tape

What to do

- Chop the leaf into small pieces.
- Grind the pieces to a pulp with a little sand in a mortar.
- Add about 25 mL of methylated spirits and stir the mixture to dissolve the colouring matter.
- Pour the solution into the measuring cylinder.
- Fit the strip of blotting paper into the cylinder so that one end is in the green solution and the other end is projecting out of the cylinder. Fasten the top with sticky tape.
- Allow to stand in a dark place for 24 hours.
- Repeat the experiment using purple leaves from a coleus plant or a prunus tree.

Question

11.5 What colours appeared on the strip of blotting paper? Did the purple leaves contain any green? Draw diagrams of the strips, recording the colours.

The flowering plant

1. The roots of a plant
   - absorb water and mineral salts
   - provide anchorage and support
   - store food.
2. The stems of a plant
   - conduct food and water to the various parts
   - support the leaves, flowers and fruits.
3. Water is pulled up the stem as the result of capillarity and evaporation from the leaves.
4. Plants manufacture glucose from carbon dioxide and water. The process is called photosynthesis. During photosynthesis oxygen is produced.
5. Respiration is the process by which plants obtain energy for growth and reproduction. During respiration carbon dioxide and water are produced.
6. Plant cells produce
   - living material (protoplasm)
   - non-living material, such as starch and cellulose.

Spelling list

absorption
anchorage
capillarity
cellophane
cellulose
chlorophyll
chloroplasts
glucose
molecule
osmosis
particle
photosynthesis
phloem
privet
protoplasm
radish
respiration
spinach
tissue
transpiration
vein
xylem

Things to do

11.6 Obtain a piece of dialysis tubing and use it instead of cellophane to demonstrate osmosis.
11.7 Germinate some wheat seeds. Mark one of the roots with ink at equal distances along it. Place the seedlings on wet blotting paper for several days. Where does growth take place in a root?
11.8 Tie a plastic bag over a branch of a plant in the garden. Observe the amount of water that collects in the bag.
11.9 Test various root vegetables and fruits for starch.

More questions

11.10 Draw a diagram of a plant cell and label the parts shown in your drawing. Which of these structures are not found in the cells of animals?
11.11 In what ways do roots resemble stems? In what ways do they differ?
11.12 What is the function of the air spaces in the spongy tissue of leaves?
11.13 Why do scientists say that all life on earth is dependent on green plants?
11.14 The leaves of most plants are broad and flat. Explain why this shape of leaf is of advantage to the plant.
11.15 All the leaves of a growing plant are thickly smeared with Vaseline on their upper and lower surfaces. Discuss the ways in which the plant would be affected.
11.16 Summarize the process of photosynthesis.
11.17 Why is photosynthesis important to animals?
11.18 How are the energy needs of a plant met? State three ways in which a plant uses energy.
11.19 Why does cutting the top of a shrub make it bushy?
11.20 When a garden shrub is transplanted, it is more likely to survive if some of the leafy branches are cut off. Why?
11.21 Why are plants often called the universal providers?
11.22 At what time of its life is a seedling able to produce its own food?
11.23 What is ringbarking? Why does it kill a tree?

Test yourself (chapter 11)

Write the answers to questions 1 to 9 in your workbook.

1. Name the organs of a plant.
2. Name the tissues that conduct water to the various parts of a plant.

3. Name the tissues that conduct food to the various parts of a plant.
4. Name the openings in a leaf that allow gases to pass in and out.
5. Name the two raw materials needed by a plant to make food.
6. Name two products of photosynthesis.
7. Name the process that releases energy in plants.
8. Where does this energy come from originally?
9. Name the small units that must be present in plant cells for food to be produced.

Choose the best answer to each of the following questions and write its letter in your workbook.

10. Which of the following is *not* needed in photosynthesis?
    (a) water
    (b) oxygen
    (c) carbon dioxide
    (d) energy.
11. The main function of the potatoes in the ground beneath a potato plant is
    (a) to absorb water
    (b) to manufacture food
    (c) to store food
    (d) to anchor the plant.
12. The leaves of plants convert
    (a) light energy to chemical energy
    (b) light energy to mechanical energy
    (c) chemical energy to light energy
    (d) light energy to heat energy.
13. The sugar in an orange was originally made in
    (a) the orange, from carbon dioxide and water
    (b) the roots, from water and salts
    (c) the leaves, from carbon dioxide and water
    (d) the leaves, from water and salts.
14. Starch is a useful storage substance in plants because it is
    (a) soluble and has high chemical energy
    (b) soluble and has low chemical energy
    (c) insoluble and has low chemical energy
    (d) insoluble and has high chemical energy.
15. When a green plant synthesizes proteins, it does so by combining a carbohydrate with
    (a) glucose
    (b) nitrogen compounds
    (c) nitrogen gas
    (d) water.
16. Consider air entering the spaces between the cells of a green leaf on a plant that is in the dark. The composition of the air changes in which of the following ways?
    (a) Oxygen is reduced, carbon dioxide is reduced.
    (b) Oxygen is reduced, carbon dioxide is increased.
    (c) Oxygen is increased, carbon dioxide is reduced.
    (d) Oxygen is increased, carbon dioxide is increased.

17. The rate of transpiration from a green plant will increase if
    (a) the soil becomes dry
    (b) the sky becomes less cloudy
    (c) some leaves are removed from the plant
    (d) the temperature falls.
18. Figure 11.21 shows a cellophane bag, containing a suspension of starch in water, dipping into an iodine solution. You are told that when starch comes into contact with iodine a blue substance is formed, and that starch particles are larger than iodine particles.

    After about two hours it would be observed that
    (a) the starch suspension is turning blue
    (b) the iodine solution is turning blue
    (c) both the starch suspension and the iodine are turning blue
    (d) there is a thin film of blue liquid on the outside of the bag.

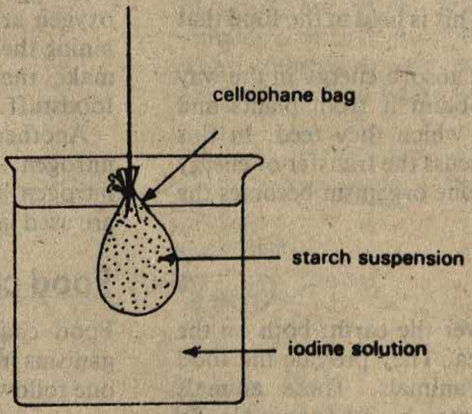


Figure 11.21

12

Energy and food chains

All living things need supplies of energy in order to survive. Plants, for example, absorb their energy from the sun and change it into chemical energy. This is held in the food that the plant makes.

Animals cannot absorb energy in the way plants can, but obtain it from plants and other animals on which they feed. In this chapter we will discuss the transfer of energy that occurs when one organism becomes the food of another.

Food

Plants grow all over the earth, both on the land and in the sea. They provide the food for plant-eating animals. These animals may, in turn, be eaten by other animals. So all the food eaten in the world must, in the first instance, have come from plants. The plants get the energy in this food from the sun.

The commonest elements in most foods are carbon, hydrogen and oxygen. Carbon and oxygen are the elements in carbon dioxide, a gas in the atmosphere. Hydrogen and oxygen are the elements in water. By combining these two common substances, plants make the compound glucose — a basic foodstuff.

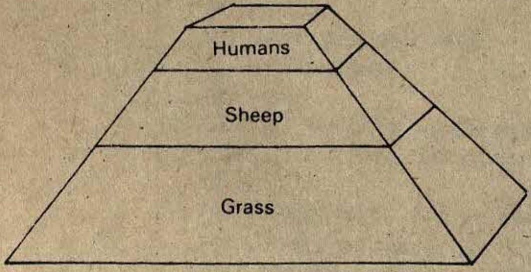


Figure 12.1: A typical food pyramid. Only ten per cent of the energy absorbed in one step is passed on in food to the next step. The other ninety per cent is used up in respiration.

Another element in some foods is nitrogen. Foods that contain combined nitrogen are called proteins. Protein foods are used in the growth of organisms.

Food chains

Food chains consist of a number of organisms in order, each being the food of the one following it. For example, the chain

grass → sheep → human

means that sheep eat grass and humans eat sheep.

As in the example above, all chains begin with a plant. (The plant is the producer; the animals are the consumers.) The plant is followed by a herbivorous animal. The remaining organisms in the chain are carnivorous.

The chain referred to above may be represented by a food pyramid, as shown in figure 12.1. The pyramid shows that the energy passed on in each case is less than that received. A sheep, for example, weighs much less than the grass it has eaten. It uses most of the energy in this grass for its bodily processes. Only a small fraction is stored in the body of the sheep as chemical energy. Some of this energy passes on to us when we eat meat from the sheep.

Most organisms live in one particular habitat. For this reason it is convenient to study a few examples of food chains from some different habitats.

The sea

There is much more plant life in the sea than on the land. Sea plants, however, are confined to the fraction of the water that receives light. This is the top 100 metres or so of the oceans. There is an abundance of raw materials for sea plants — plenty of water and plenty of carbon dioxide dissolved in the water. The water also contains essential minerals.

Many of the plants are microscopic; some are even single-celled. In some waters these microscopic plants exist in countless millions. Because they are so small they float very easily and hence remain near the surface, where they receive light. They are called phytoplankton. The name comes from *phyton* meaning "plant" and *plankton* meaning "drifting". Figure 12.2 shows the shapes of some of these tiny plants.

Phytoplankton are so tiny that the raw materials they use can quickly diffuse through them. Likewise, waste products can quickly diffuse out from them. Phytoplankton are eaten by small shrimp-like animals that drift around near the surface. These animals are the zooplankton. (They are also shown in figure 12.2.) They form the

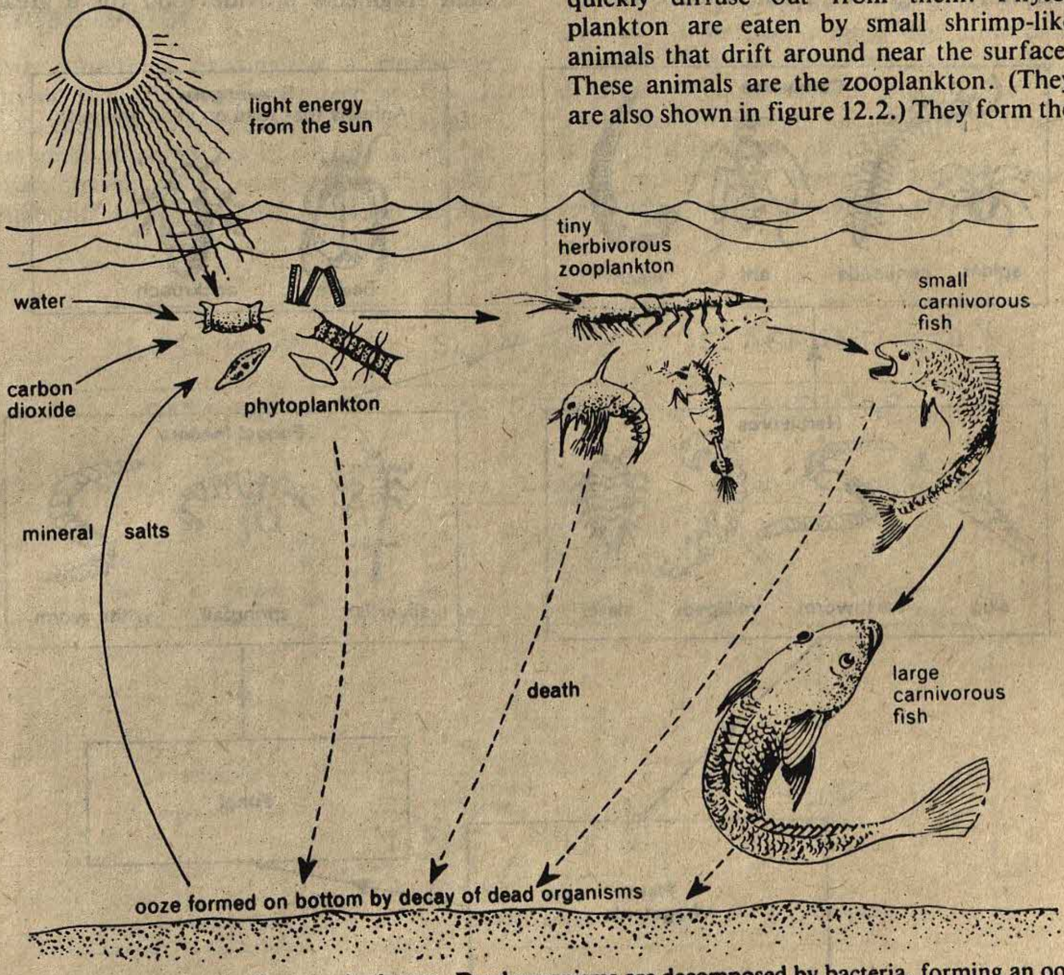

light energy from the sun
water
carbon dioxide
phytoplankton
tiny herbivorous zooplankton
small carnivorous fish
mineral salts
death
large carnivorous fish
ooze formed on bottom by decay of dead organisms

Figure 12.2: The cycle of energy in the sea. Dead organisms are decomposed by bacteria, forming an ooze on the bottom. Essential minerals from this ooze may be carried to the surface by upwelling currents.

food of larger animals such as small fish, which in turn are eaten by larger fish.

The Antarctic oceans are very rich in zooplankton. This is because these oceans are rich in salts, which have been brought up from the ooze on the ocean floor by currents.

Soil

Under suitable conditions soil can support an abundance of life. These conditions are the presence of water, food and warmth. Water is usually kept in the soil by a cover of litter. This litter consists mainly of leaves that fall from grasses, shrubs and trees.

The animals living in the soil require moist conditions. They die if exposed to dry air for any length of time. They are adapted to resist this drying out to a certain extent in a number of ways. For example, snails have a shell into which they can retire. Slaters have a tough covering and earthworms secrete mucus. All of the animals living in the soil instinctively move from bright light to darkness. (Inside the soil — their natural environment — it is dark.)

The energy for the organisms living in the soil comes from the litter that accumulates on it. The litter rots — it is decomposed into humus by bacteria and fungi. The rotting plant fragments provide food for a great

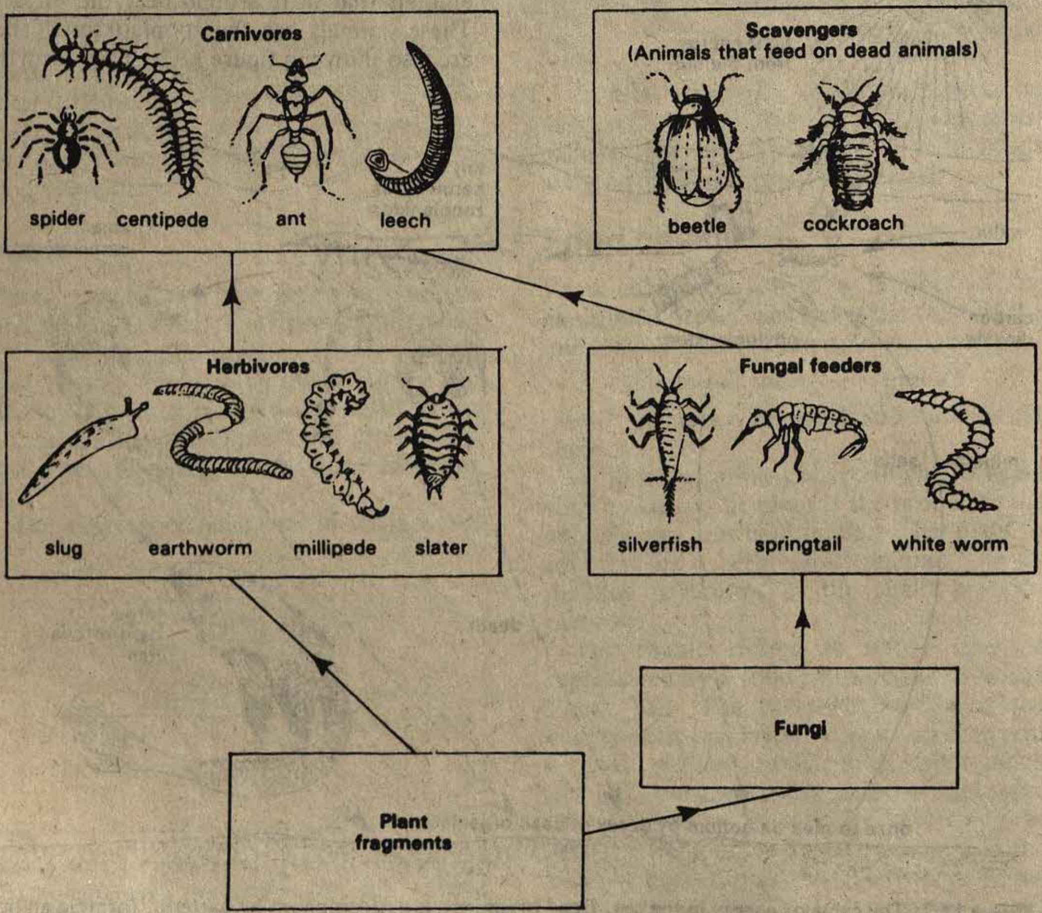


Figure 12.3: Food web for some organisms living in the soil.

variety of herbivorous animals, such as amphipods, slaters, worms and millipedes. These in turn are eaten by carnivores such as spiders, centipedes and ants. Some animals, such as silverfish and springtails, feed on fungi. Fungi get their energy from the rotting vegetation on which they grow. Other animals, called scavengers, live only on dead animals. Cockroaches and beetles are typical scavengers in the soil community.

These various food chains may be shown on one diagram, called a food web. Figure 12.3 is a food web for some organisms living in the soil.

Fresh water

The conditions existing in a freshwater stream vary. There may be deep pools with slow currents, fast stretches with waterfalls, or small stagnant pools cut off from the main stream. The organisms living under these different conditions must be adapted to them in order to survive. To resist strong currents some animals use strong legs to cling to stones, some hold on with suckers, and others build webs and hook on to them.

Stagnant water contains little dissolved oxygen. To live in stagnant or slow-moving pools, animals must have special methods of getting oxygen supplies. Some trap supplies of air at the surface and take these supplies down with them. Some come to the surface and breathe through tubes, or gulp in air. Others have very efficient gills that extract dissolved oxygen from the water.

In a fast-flowing stream the supplies of algae and plankton are low. The main source of food energy is detritus — decaying leaves and twigs from overhanging vegetation and the remains of dead plants and animals. The detritus collects in the ooze at the bottom of pools. In slow streams some additional food is supplied by water plants that have taken root, and by algae. Figure 12.4 shows some food chains in a freshwater creek.

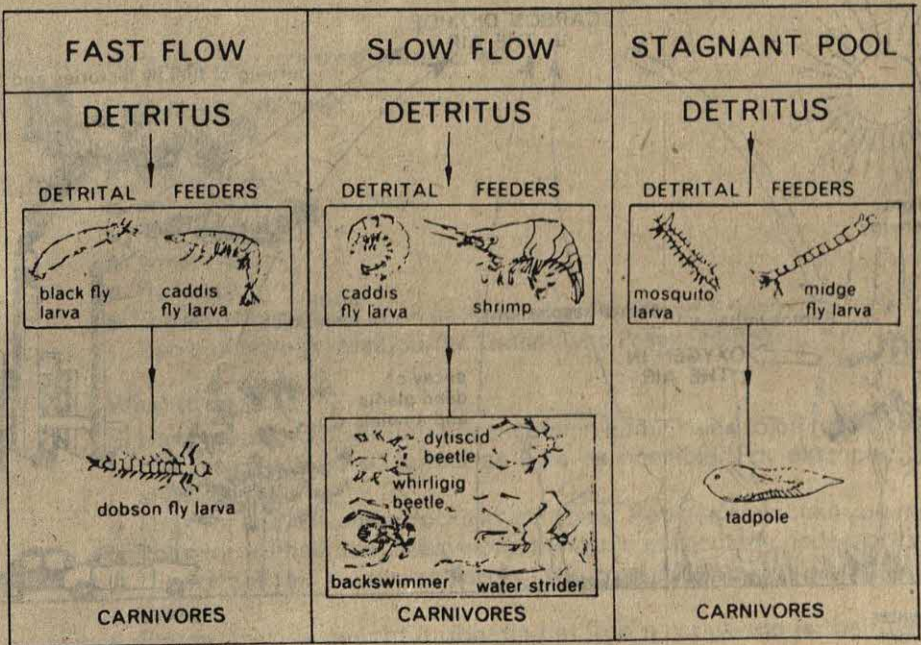


Figure 12.4: Some food chains in a freshwater creek under various conditions. Crayfish, not shown in the figure, eat pieces of dead animals. They are the scavengers of the freshwater creek.

The circulation of carbon and oxygen in nature

In all the examples of food chains discussed the first link in the chain has been a plant or some dead and decaying vegetation. This vegetable material, whether dead or alive, contains compounds of the elements carbon, hydrogen and oxygen. These compounds are carbohydrates. They contain chemical energy, which is passed on when the vegetable material is eaten.

All organisms following plants in the food chain also have energy stored in carbohydrates. This energy is released in respiration, which occurs in all living cells. In respiration, carbohydrate combines with oxygen to form carbon dioxide and water.

The energy in carbohydrates is also released when organisms die and decompose. In dead material the carbohydrates are broken down by decay. This decay is caused by bacteria and fungi that feed on the dead material. As the bacteria and fungi respire, carbohydrate from the dead material is converted to carbon dioxide and water vapour.

In all cases, the breaking down of carbohydrates during respiration produces energy, carbon dioxide and water vapour. Carbon dioxide and water vapour are returned to the atmosphere; they are the raw materials for photosynthesis. Whereas photosynthesis uses carbon dioxide and releases oxygen, respiration uses oxygen and releases carbon dioxide. Thus the balance of these two gases in the atmosphere is maintained. The reactions may be summarized as follows.

PHOTOSYNTHESIS (in green plants only)

$$\text{carbon dioxide} + \text{water} + \text{energy} \longrightarrow \text{carbohydrate} + \text{oxygen}$$

RESPIRATION (in all organisms)

$$\text{carbohydrate} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

The facts discussed above are shown diagrammatically in figure 12.5.

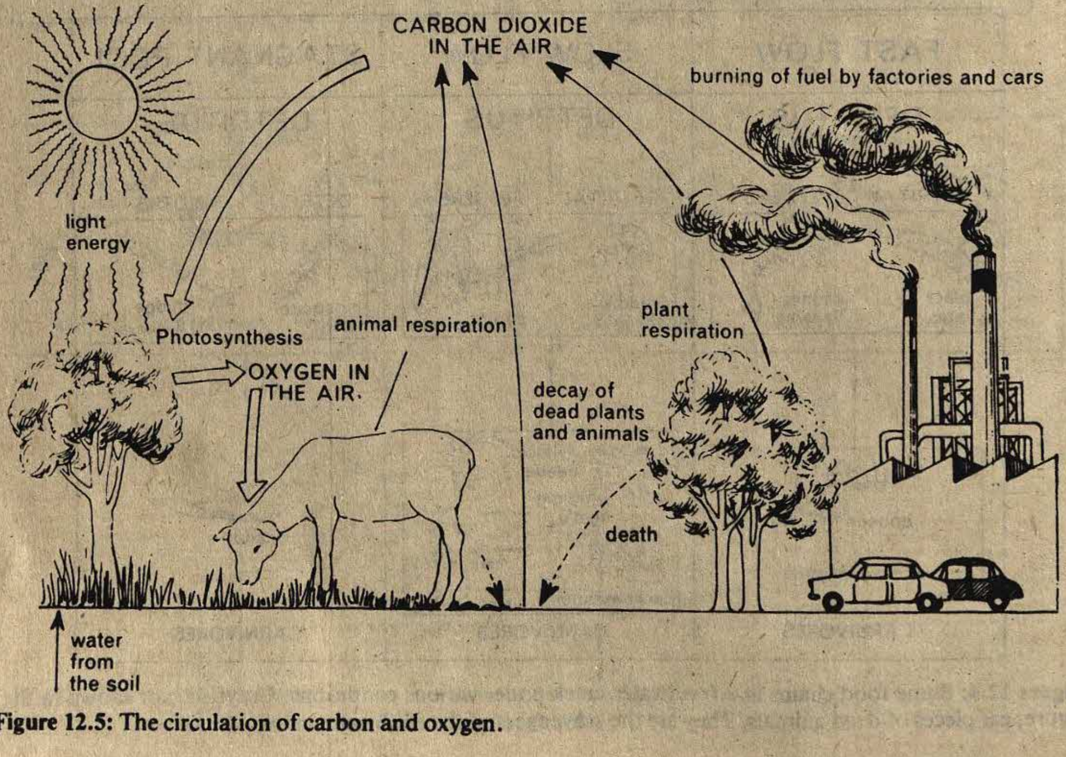


Figure 12.5: The circulation of carbon and oxygen.

EXPERIMENT 12.1

Searching for animals (in the school playing area or a paddock)

Each group will need:

- screw-top jars
- small hand fork

What to do

- Choose a sunny morning during a warm season, ideally when the soil is damp.
- Search the following areas carefully and quietly in small groups (a large noisy group will send most animals into hiding):
  - open areas of grassland
  - under stones and rotting logs
  - under leaf litter
  - on the bark, leaves and flowers of any shrubs or trees
  - an area of damp soil to a depth of 30 cm.
- Note any birds present and try to identify them.
- Place any animals you collect in screw-top jars. Collect only one specimen of each kind.
- Back at school or home, try to identify each animal collected. Write down where it was found and what food it eats.

Question

12.1 Make up some possible food chains from some of the animals you have identified.

EXPERIMENT 12.2

An excursion to a freshwater creek

Each group will need:

- dip net
- screw-top jars
- corked specimen tubes
- methylated spirits
- small brush
- rucksack
- suitable handbook, such as *Australian Pond and Stream Life* by J. Child (a Periwinkle book; Melbourne: Lansdowne Press, 1969).

What to do

- Have a discussion before the excursion about rules to be followed so that the creek will be disturbed as little as possible. For example, no litter should be left.
- Look for animals under rocks in the creek. Replace any rocks you move.
- Look for animals sheltering along the bank, particularly under rocks.
- Dip for animals in various parts of the creek — in fast, slow and stagnant water.
- Empty animals caught in the dip net into a screw-top jar half-filled with water from the creek.
- Place any animals caught above the water in dry jars.

- At the completion of the excursion, place the specimens you wish to keep in methylated spirits in corked specimen tubes. Tiny animals may be picked up with a wet brush. The other animals should be returned live to the creek.
- Back at school or home, examine each animal and try to identify it. Make a list of the names and state in which part of the creek each animal was found.
- Try to find out what adaptations each animal has and what food it eats.

Question

12.2 Make up a possible food web of the animals you have identified.

Energy and food chains

- All living things need energy to survive. The sun is the source of this energy.
- Green plants change light energy from the sun into chemical energy. This chemical energy is held in the food made by green plants during photosynthesis.
- Animals obtain chemical energy from the food they eat. Herbivores eat plants. Carnivores eat other animals.
- Food chains always start with a plant. A typical food chain is

  plant → herbivore → carnivore → another carnivore.

  The energy transferred in each case is less than the amount received. Most energy is used by the organism in living.
- The energy needed for living is released from food by the process of respiration. This process occurs in the cells of the organism.

Spelling list

beetle
carnivore
centipede
detritus
fungi
fungus
herbivore
herbivorous
larva
millipede
ooze
phytoplankton
plankton
pyramid
scavenger
zooplankton

Things to do

12.3 Visit a museum. Ask to be directed to models of communities in which preserved specimens are used. Find out the special adaptations of the animals, and the food they eat. Make up possible food chains.

12.4 Visit a zoo. Select a few animals that particularly interest you. Examine the adaptations they have for surviving and eating that are peculiar to them. Make up a food chain for each animal.

More questions

12.5 Write down two food chains from each of the following habitats:
- (a) the sea
- (b) a freshwater creek
- (c) the soil
- (d) an open paddock.

12.6 Refer to figures 12.3 and 12.4. Write down five different food chains from each of these figures.

12.7 What is photosynthesis? Explain its importance to all living things.

12.8 Which has more plant life — the land or the sea? Explain why this should be so.

12.9 Why must food chains always start with a plant?

12.10 Why are plankton found only near the surface of the sea?

12.11 Why are Antarctic waters rich in plankton?

12.12 What is a food web? Make up a food web using the following organisms: dingo, grass, insects, rabbit, sheep, anteater.

12.13 Make up a food web using the following: kookaburra, lizards, frogs, insects, plants, snails, small birds, snakes, mice.

12.14 What is respiration? Compare respiration with photosynthesis. Cover the following points:
- (a) where each process occurs
- (b) whether the process is energy-absorbing or energy-producing
- (c) the raw materials required for each process
- (d) the chemical products of each process.

12.15 For each link in a food chain the energy passed on is less than that received. Give an explanation of this fact.

12.16 Explain why the organisms at the end of a food chain are larger and fewer in number than those near the start of the chain.

12.17 What are the raw materials required by phytoplankton? How do they enter the organisms?

12.18 Draw a simple carbon cycle.

12.19 The Crown of Thorns starfish has been destroying the Great Barrier Reef, in Queensland, by eating the tiny coral polyps. A few years ago this destruction was not occurring. Explain how this situation may have developed. (R)

12.20 Measurements taken by scientists show that the percentage of carbon dioxide in the atmosphere is gradually increasing. Give an explanation of this fact. What is likely to be the long-term effect of this increase, in your opinion? (R)

Test yourself (chapter 12)

Write the answers to questions 1 to 5 in your workbook.

1. What is the name given to the material formed from decaying leaves and twigs and the remains of dead animals?
2. The microscopic animals occurring in large numbers in the ocean are called _______.
3. The microscopic plants in the ocean are called _______.

4. A food pyramid is a way of showing that (a) ______ is (b) ______ as it passes from one organism in a food chain to the next.
5. The diagram below represents a complete food chain, the empty box representing the first organism in it. What type of organism must it be?

☐ → tadpole → duck → human

Choose the best answer to each of the following questions and write its letter in your workbook.

6. Carbon dioxide is returned to the atmosphere by
   (a) photosynthesis
   (b) transpiration
   (c) the decay of dead organisms
   (d) osmosis.
7. One of the following shows a possible path of energy in nature. It is
   (a) sun → green plant → fungus
   (b) sun → fungus → green plant
   (c) green plant → sun → fungus
   (d) fungus → sun → green plant.

13

The flowering plant: reproduction

As you saw in *Concepts of Science 2*, fossils are clues to the kind of life that existed in the distant past. Examination of fossils shows us that the first plants appeared in the oceans. They were algae. (Today's seaweeds are a large variety of algae.)

From the seaweeds the first land plants developed. They were mosses and ferns. They reproduced from spores and survived only in moist conditions. Plants that could survive in drier places appeared later. These reproduced from seeds. The pine tree is a plant of this kind; its seeds are exposed and unprotected.

One hundred and fifty million years ago, plants appeared with protected seeds. These were the flowering plants. There are 250 000 different varieties throughout the world today. They range from gum trees and bananas to wheat and paspalum.

The flower — the organ of reproduction

The flower is the plant's organ of reproduction. Figure 13.1 shows a typical flower.

Flowers form on the tips of the shoots of a mature plant. Special hormones cause the formation of the cells that grow into a flower. Most flowers contain both male and female parts: the stamen and the carpel. The carpel consists of the ovary, style and stigma. Table 13.1 lists the various parts of the flower and explains their functions.

Table 13.1: The parts of a flower

Part	Description	What it does
receptacle	swollen tip of a stem	bears the flower
sepals	small leaves	protect the young flower as a bud
petals	usually showy and leaflike	advertise the flower to insects and birds
stamen	stalk bearing the anther, which contains pollen sacs	is the male part and produces pollen
ovary	a hollow swollen part at the bottom of the flower	is the female part and contains the ovules; the wall of the ovary becomes the fruit
ovule	small part attached to the inside wall of the ovary	contains female sex cells; it grows into a seed when one of these cells is fertilized
style	the stalk above the ovary	supports the stigma
stigma	the sticky top of the style	receives and holds the pollen

The ovaries of some flowers have only one ovule, as in the case of the almond. The ovaries of other flowers have more than one ovule, as in the case of the peanut, which usually has two.

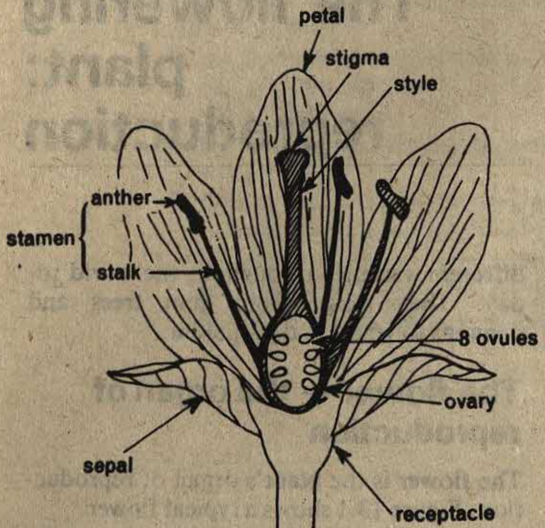


Figure 13.1: Section through a typical flower showing its main parts. The ovary of this flower contains eight ovules.

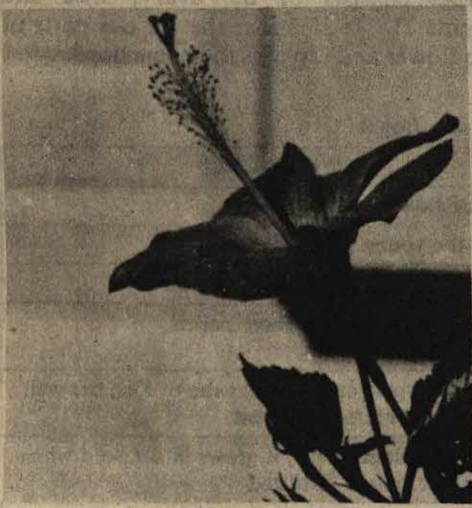


Figure 13.2: The flower of the hibiscus shrub. Notice the divided stigma at the top and the large number of stamens branching from the style.

Pollination

As the pollen ripens, the anthers swell and eventually split. This releases the pollen. Some of it may be deposited and held on the stigma of the same flower, but most of it is scattered. This scattering may be done by wind, birds or insects. In the process some of the pollen may be transferred to the stigma of another flower. If this flower is of the same variety, fertilization can occur.

Fertilization

When a pollen grain is caught by the stigma, it proceeds to grow down through the style into the ovary. The male sex cells pass down the pollen tube into the ovary. Figures 13.3 and 13.4 show this in detail.

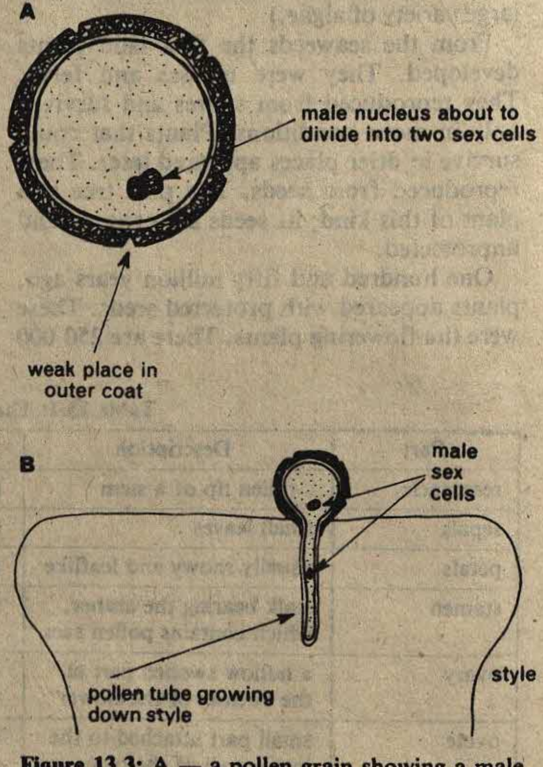

A
male nucleus about to divide into two sex cells
weak place in outer coat
B
male sex cells
style
pollen tube growing down style

Figure 13.3: A — a pollen grain showing a male nucleus about to divide. B — a pollen tube growing down into a style. The male sex cells will move along this tube into an ovule where fertilization may occur.

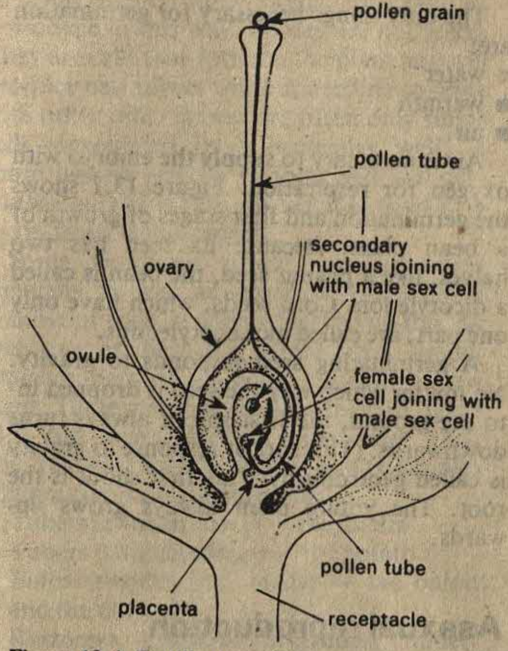

pollen grain
pollen tube
secondary nucleus joining with male sex cell
ovary
ovule
female sex cell joining with male sex cell
pollen tube
placenta
receptacle

Figure 13.4: Fertilization. The ovary contains one ovule. A male sex cell joins with a female sex cell to form the first cell of the embryo (the zygote). The other male sex cell joins with the secondary nucleus to produce food for the embryo. After fertilization the seed commences to grow inside the ovule.

Fertilization is the joining together, in the ovule, of a female sex cell and a male sex cell from the pollen tube. This new cell is the first cell of the embryo plant and is called the zygote.

After fertilization,

- the zygote grows into the embryo
- the ovule grows into the seed
- the ovary grows into the fruit.

Dispersal of seeds

As the seeds grow, so does the ovary. With bean seeds, the ovary is the pod that holds them. When the bean seeds are mature, the pod dries and splits and the seeds fall to the ground. The pods of lupins split with considerable force so that the seeds are ejected some distance from the parent plant. Thistle seeds are covered with downy filaments and may be blown for kilometres by the wind.

The ovary walls of many flowers form succulent fruits such as plums, blackberries and tomatoes. Birds eat the smaller berries; larger animals eat the larger fruits. The seeds pass through their bodies undamaged and

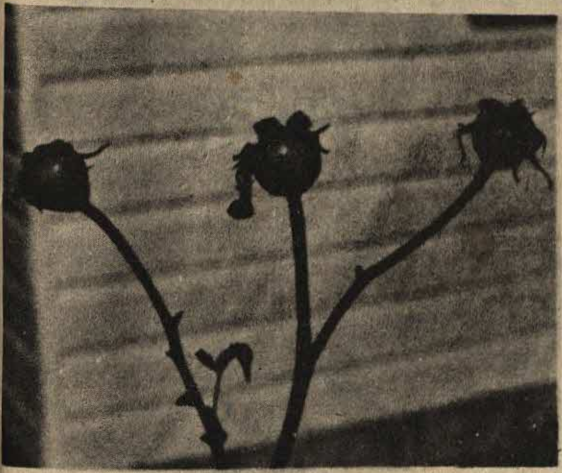


Figure 13.5: Fruit on a rose bush. Notice the withering sepals on top of the fruit. This fruit is a swollen receptacle surrounding the ovary.

Figure 13.6: Flower and young fruit of the lemon. Notice the stigma and style on the top of the little lemon.

thus may be dispersed quite considerable distances from the parent bush or tree. You disperse seeds when you eat an orange and spit out the pips.

Germination

The mature dry seed is in a resting period between two stages of growth. Seeds can remain in this condition for a long time. Some types of seeds can remain alive for a year; others can stay alive for over a hundred years. However, it is a common fallacy that seeds can remain alive indefinitely. None of the seeds found in ancient Egyptian tombs could be made to germinate; the embryos in these seeds died when they had used up the supply of food in the seed.

Germination is the breaking out of the embryo plant through the seed coat. The embryo requires energy to do this. This energy comes from the starch within the seed. The embryo changes this starch into glucose, which is used for respiration.

Photosynthesis does not take place when a seed is germinating. For this reason light is not necessary. Neither is soil necessary. The young plant obtains all its nutrients from within the seed.

The only things necessary for germination are:

- water
- warmth
- air.

Air is necessary to supply the embryo with oxygen for respiration. Figure 13.7 shows the germination and first stages of growth of a bean plant. Because its seed has two halves, like a peanut seed, the bean is called a dicotyledon. Corn seeds, which have only one part, are called monocotyledons.

A germinating seed responds to gravity. No matter which way the seed is dropped into the ground, the first sprout always turns downwards. (This sort of response to gravity is called geotropism.) This first shoot is the root. The young plant always grows upwards.

Asexual reproduction

Some organisms are able to reproduce asexually. One such reproduction method is the simple division of a cell to form two new cells. Seaweeds and bacteria reproduce in this way: seaweed does not form a flower nor does it form seeds.

Another way of reproducing asexually is

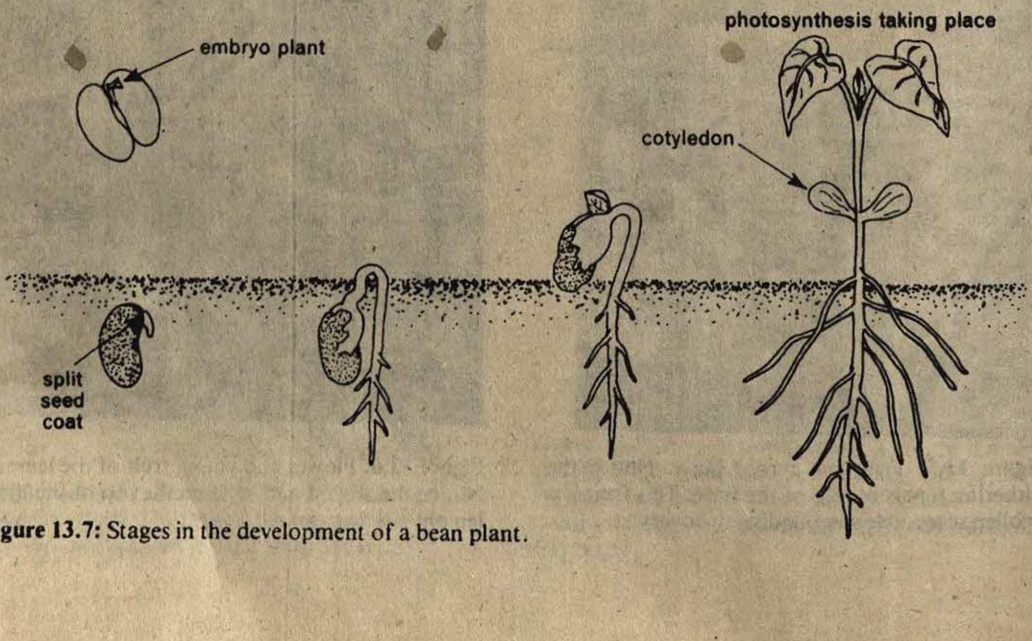


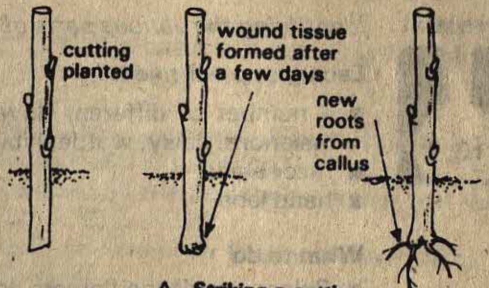
Figure 13.7: Stages in the development of a bean plant.

by using spores. Mushrooms, for example, reproduce in this way. Spores are not seeds. They are cells that form on the plant and will produce new plants without needing to unite with other cells. Spores are often only single cells surrounded by a protective wall. A spore has no reserve of food and will germinate only if it falls on suitable food in a warm moist environment.

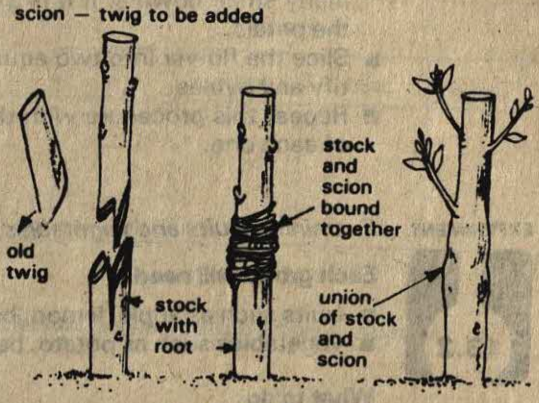
Some flowering plants can reproduce asexually as well as sexually. There are a number of ways in which they can do this. In each one of these the parent plant simply detaches part of its body to form a new plant. These methods are illustrated in figure 13.9 and investigated in experiment 13.4. The following list of methods gives examples that are common garden plants.

- Tubers (swollen roots) — the dahlia
- Tubers (swollen stems) — the potato
- Bulbs (swollen leaf bases) — the onion and the daffodil
- Rhizomes (swollen horizontal underground stems) — couch grass, paspalum and iris
- Corms (swollen upright underground stems) — the gladiolus
- Runners (horizontal stems above the ground) — the strawberry.

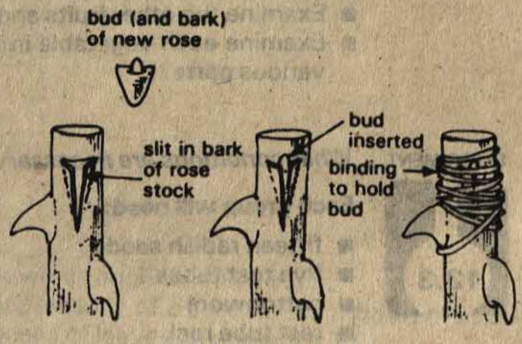
Plants may also be propagated artificially by taking and planting cuttings, grafting and budding. These are also asexual methods and are illustrated in figure 13.8.



A **Striking a cutting**



B **One type of grafting**



C **Budding a rose**

Figure 13.8: Artificial propagation of plants. A — cuttings; B — grafting; C — budding.

EXPERIMENT

13.1

Identifying the various parts of some flowers

Each group will need:

- a number of different flowers such as nasturtium, jonquil, sweet pea, lasiandra, daisy, wattle, hibiscus and any of the lilies
- razor blade
- hand lens

What to do

- Select one of the flowers. Identify the stamens, styles, sepals and petals. If you have selected a daisy or some wattle, notice that it is made up of many small flowers. If it is a single flower that you have selected, count the petals.
- Slice the flower into two equal halves. Look for the ovary and try to identify any ovules.
- Repeat this procedure with the other flowers, writing a short description of each one.

EXPERIMENT

13.2

Examining fruits and vegetables

Each group will need:

- fruits such as apple, lemon, banana, passionfruit, watermelon
- vegetables such as potato, bean, carrot, pea, celery

What to do

- Examine the apple. What part corresponds to the stem and what part to the withered style or sepals?
- Notice the core of the apple — this is the ovary and contains the seeds. The main part of the apple is the swollen receptacle (see figure 13.1).
- Examine the other fruits and try to compare them with the apple.
- Examine each vegetable in turn. Decide which are fruits, and identify the various parts.

EXPERIMENT

13.3

What conditions are necessary for the germination of seeds?

Each group will need:

- fifteen radish seeds
- five test tubes
- cottonwool
- test tube rack
- black plastic sheet
- beaker
- tripod
- Bunsen burner

What to do

- Boil some water in a beaker for five minutes to drive out all the dissolved air. Allow the water to cool.

- Place three seeds on dry cottonwool in one test tube. Mark this tube A.
- Place three seeds on wet cottonwool in test tube B.
- Repeat for test tube C.
- Place three seeds on wet cottonwool in test tube D (same situation as B).
- Place three seeds in a little boiled water in test tube E.
- Wrap black plastic sheeting around all the test tubes except test tube C. This is to exclude the light from A, B, D and E.
- Place test tube D in a refrigerator and the other three in a warm place.
- Examine the seeds after 4 or 5 days.
- Tabulate your results as follows:

Seeds	Root growth after *x* days	Conditions			
		air	water	heat	light
A					
B					
C					
D					
E					

Question

13.1 What conditions are necessary for the germination of seeds?

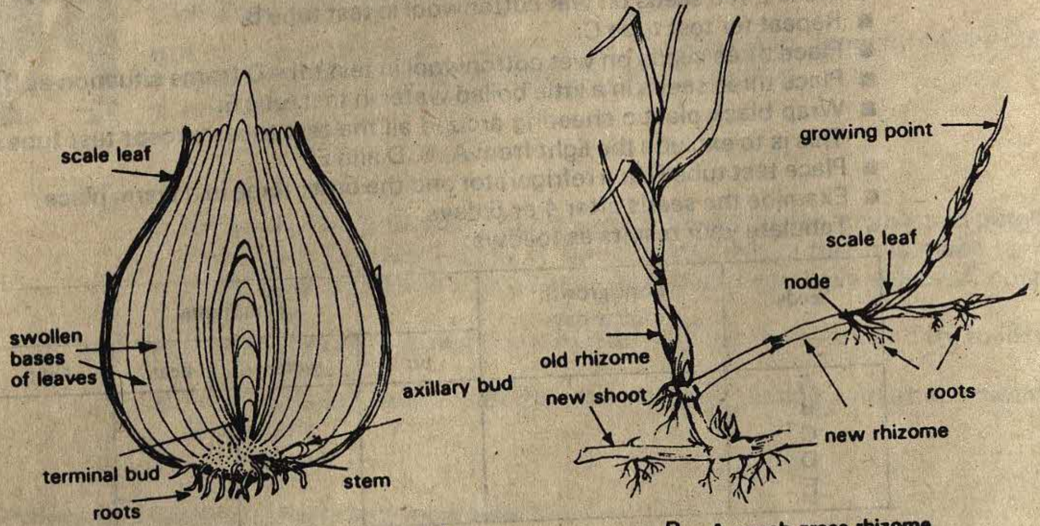
EXPERIMENT 13.4 *Investigating asexual reproduction in plants*

Each group will need:

- onion bulb
- couch grass
- potato with eyes
- dahlia tuber
- gladiolus corm
- strawberry runner
- sharp knife

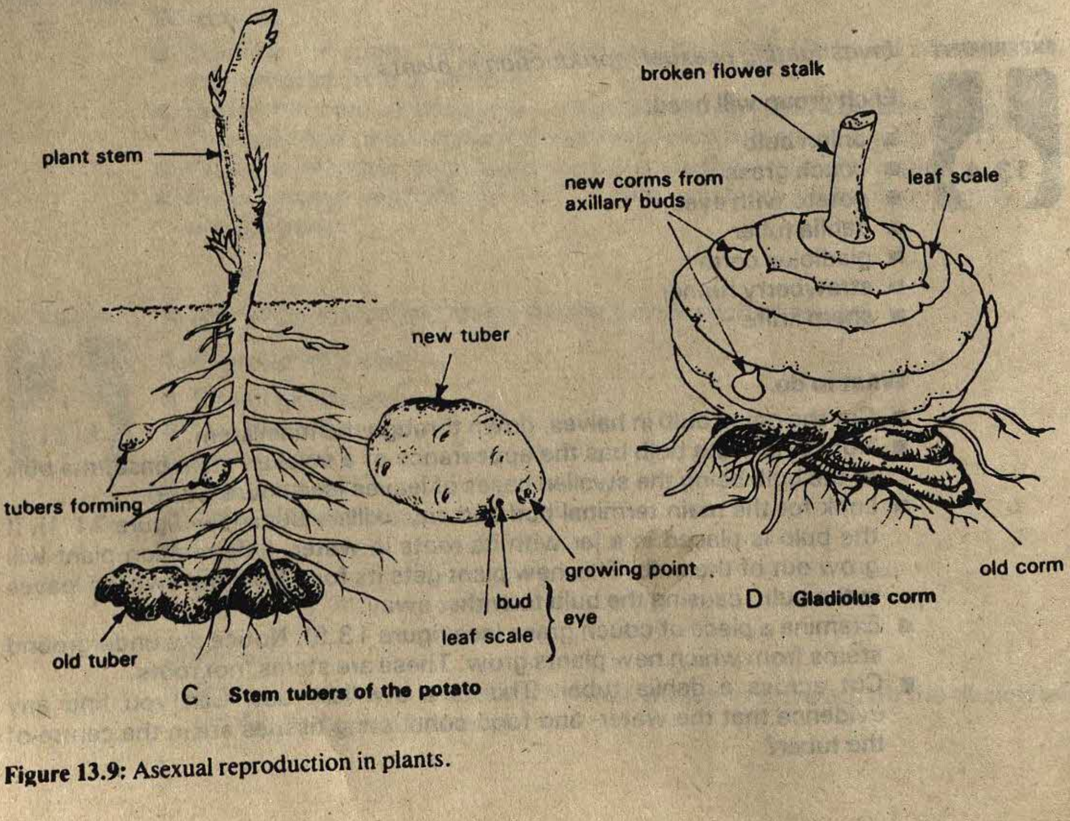
What to do

- Cut the onion bulb in halves, down through the main stem.
- Notice how the bulb has the appearance of a swollen stem base, the bulk of the bulb being the swollen bases of leaves (see figure 13.9).
- Look for the main terminal bud and any axillary buds (see figure 11.1). If the bulb is placed in a jar with its roots in water, a new onion plant will grow out of the bulb. This new plant gets its food from the swollen leaves in the bulb, causing the bulb to wither away.
- Examine a piece of couch grass (see figure 13.9). Notice the underground stems from which new plants grow. These are stems, not roots.
- Cut across a dahlia tuber. This is a swollen root. Can you find any evidence that the water- and food-conducting tissues are in the centre of the tuber?



A Vertical section through an onion bulb

B A couch grass rhizome



D Gladiolus corm

C Stem tubers of the potato

Figure 13.9: Asexual reproduction in plants.

- Look at the eyes on the potato. They are growing buds surrounded by leaf scale. Cut across the potato and look carefully at the exposed cut. Can you see any evidence to indicate that the conducting tissues are towards the edge rather than in the centre?
- Examine the gladiolus corm. Notice the leaf scars and the new buds growing from what appear to be leaf axils. (See figure 11.1.)
- Examine the strawberry plant. What is the difference between this plant and couch grass?

The flowering plant: reproduction

Sexual reproduction

- A pollen grain sticks to a stigma.
- The pollen tube grows down the style into an ovule.
- A male sex cell joins with a female sex cell to form the zygote.
- The zygote is the first cell of the embryo.
- The ovule forms the seed; the ovary forms the fruit.
- Germination requires air, warmth and water; it does not require light or soil.

Asexual reproduction

- Methods used are bulbs, tubers, corms, rhizomes, runners and cuttings.

Spelling list

alga
algae
anthers
corm
cotyledon
dicotyledon
embryo
geotropism
germination
monocotyledon
nucleus
ovary
ovule
pollen
receptacle
rhizome
sepal
spore
stamen
succulent
tuber
zygote

Things to do

13.2 Germinate two pea seeds in a glass jar of loose potting mixture. After germination, carefully cut off the seed from one seedling. Compare the subsequent rates of growth of the two seedlings. What do the results indicate?

13.3 Grow an onion bulb in a glass jar partly filled with a mixture of sand and soil. Leave most of the bulb exposed above the mixture. What do you conclude?

13.4 Plant a bean seed and a corn grain. Compare the germination of each.

More questions

13.5 Explain fully why couch grass is difficult to eradicate from a garden.

13.6 Draw a section through a flower. Name the parts. Which are the male parts and which are the female parts?

13.7 What part of the flower eventually becomes the seed?

13.8 What is the function of the sepals?
13.9 What is pollination?
13.10 Explain how fertilization occurs.
13.11 What happens to the flower after fertilization?
13.12 What happens to the flower if fertilization does not take place?
13.13 Why do packets of seeds sold in shops have the date stamped on them?
13.14 Could you grow some peanut plants from a packet of roasted peanuts? Explain.
13.15 What is germination? What must be present for germination to occur?
13.16 What is the difference between
  (a) pollination and fertilization?
  (b) germination and fertilization?
13.17 When we eat bananas, are we eating fruit or seeds or both? Where are the banana seeds?
13.18 What is oatmeal? Why is it so nourishing? (R)
13.19 Potatoes can be grown from seeds or pieces of potato. Why does a potato farmer grow them from pieces of potato and why does a plant breeder grow them from seeds? (R)
13.20 Paspalum grass on footpaths is a nuisance because of the ergot on the stalks. What is ergot? (R)

Test yourself (chapter 13)

Write the answers to questions 1 to 4 in your workbook.

1. In flowering plants, the male reproductive cell is transferred from the anther to the stigma of a flower. What is the name given to this process?
2. What is the name of the process in which the male reproductive cell joins with the female reproductive cell?
3. What is the name given to the particle formed by the union of the male and female reproductive cells?
4. Figure 13.10 shows the parts of a flower. Name the parts labelled A, B, C, D, E and F.

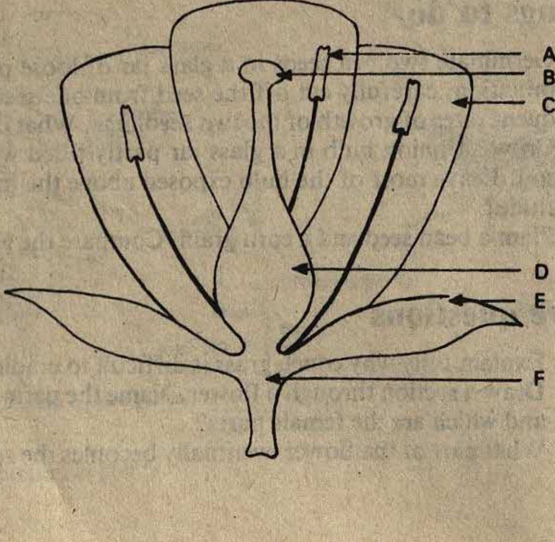


Figure 13.10

Choose the best answer to each of the following questions and write its letter in your workbook.

5. If all the flowers were removed from a plant as they appeared, the plant
   (a) would die
   (b) could not produce seeds
   (c) could not make more food
   (d) would stop producing flowers.
6. We know that the dahlia tuber is a swollen root because
   (a) it contains a lot of starch
   (b) it is formed in the ground
   (c) its conducting tissues are in its centre
   (d) it has an elongated shape.
7. The main eating part of an apple is formed from the
   (a) ovary
   (b) ovule
   (c) receptacle
   (d) sepal.
8. Which one of the following groups contains only fruits?
   (a) avocado, squash, turnip
   (b) onion, melon, orange
   (c) marrow, parsnip, almond
   (d) almond, pawpaw, walnut.

14

Reproduction in mammals

In sexual reproduction, a new individual is formed by the joining together of male and female sex cells. In most species of flowering plants one individual produces both kinds of sex cells. However, in higher animals such as mammals, the two kinds of cells are produced in different individuals — the male and the female.

In this chapter we will examine sexual reproduction in placental mammals. This is of particular interest to us, because we are placental mammals.

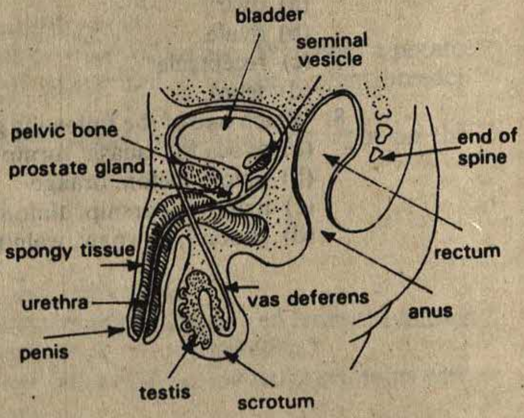


Figure 14.1: Reproductive organs of the human male.

The reproductive system

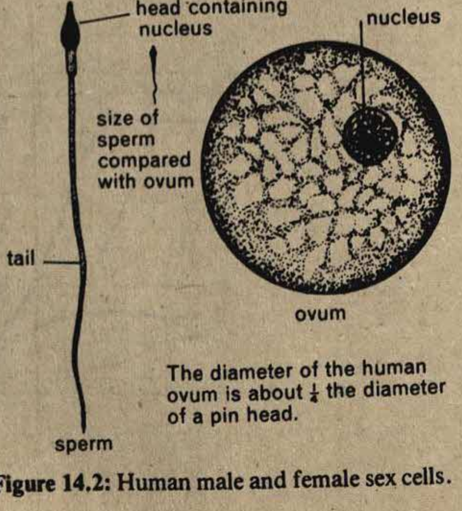
The reproductive system in placental mammals consists of

- organs to produce sex cells in each of the sexes (these sex cells are called gametes)
- organs to transfer the male gametes to the female's body
- organs to allow the development of the zygote in the female.

Male reproductive system

Male sex cells, called sperms, are made in the two testes of the mature male. The testes are held in a sac called the scrotum. Millions of tiny sperms are made in each testis.

A separate tube called the vas deferens transfers the sperms from each testis into the urinary system. Only in the male is the reproductive system connected to the urinary system. Figure 14.1 shows how the urethra in the male is common to the urinary and reproductive systems. The urethra is the tube



The diameter of the human ovum is about ¼ the diameter of a pin head.

Figure 14.2: Human male and female sex cells.

carrying urine from the bladder for discharge through the penis. During union between the sexes it carries seminal fluid containing sperms. The seminal fluid is secreted by the seminal glands shown in figure 14.1.

Figure 14.2 compares human male and female sex cells. The tiny sperm has a long tail. By moving this tail it is well adapted to swim in the seminal fluid. The larger, round, ovum needs no such adaptation since the sperms move towards it.

Female reproductive system

Female sex cells are called eggs or ova. They are made in the two ovaries of mature females. Whereas the male mammal makes millions of sperms, the female mammal makes only a few ova. Furthermore, these ova are made only at certain times.

After the ova have fully developed they pass through the oviducts and thence into the uterus. (See figure 14.3.) The uterus, commonly called the womb in humans, leads to the vagina. This is the organ that opens to the exterior.

Mating

When the male and female mate, the penis of the male is inserted into the vagina of the female, where semen is ejected by the penis. This seminal fluid contains millions of sperms. The free-moving sperms find their way in large numbers from the vagina to the uterus and thence into the oviducts.

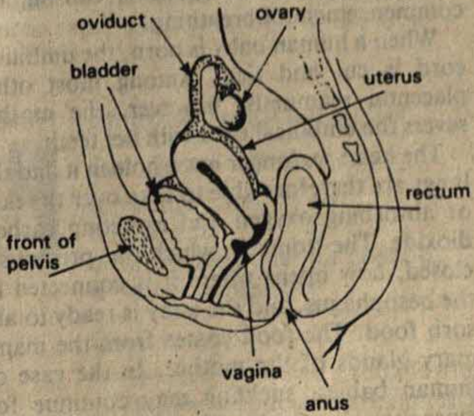


Figure 14.3: Reproductive organs of the human female.

Mating between the sexes of most placental mammals occurs only at certain periods of the year. These periods are called the mating seasons and at these times the female is said to be "on heat". She experiences a desire to mate and usually emits an odour that attracts the male; this is accompanied by a shedding of eggs into the oviduct. Thus the male and female join at a time when the male sex cells have the greatest chance of fertilizing the eggs in the female.

The mating cycle varies from species to species. It is only five days with rats, and about six months with dogs. The female dog can only *conceive* at two particular periods in a year.

The female reproductive cycle is quite different in humans, apes and some monkeys. In women it is called the menstrual cycle and occurs about every 28 days (Latin: *mensis*, meaning "month").

The menstrual cycle

Menstruation (commonly called "a period") is the discharge of a bloody fluid through a woman's vagina. It takes place approximately every month of a woman's reproductive cycle, except when she is pregnant.

About 14 days after the beginning of menstruation, a mature ovum is released from the ovary. For the next 14 days or so (the second half of the cycle), the ovary releases a hormone called *progesterone*. This hormone causes the walls of the uterus to thicken and become more muscular and richer in blood. In this way the uterus is prepared to receive an embryo, should the ovum be fertilized in the oviduct.

If the ovum is not fertilized it soon disintegrates and is absorbed by body tissues. The lining of the uterus breaks down and is discharged through the vagina — this is the bloody discharge of menstruation. Menstruation usually lasts 2–5 days.

In the first half of the cycle after menstruation, the ovary produces a hormone called *oestrogen*. At this time the lining of the uterus is repaired. Oestrogen remains in control of the system until the new ovum is released from the ovary. And so the cycle goes on.

Fertilization

Fertilization occurs in the oviduct. It happens when a sperm meets and penetrates the surface of an egg. The fertilized egg, called a zygote, begins to grow while still in the oviduct, forming a mass of cells called the embryo. On the embryo an outgrowth develops; this is the beginning of the placenta, an organ that enables food and wastes to be passed between embryo and mother. The embryo passes down the oviduct and becomes embedded in the wall of the uterus, through the placenta.

Development of the embryo

The young of placental mammals have a long period of development within the mother. This period ranges from twenty days for mice to almost two years for elephants. For humans it is about 280 days.

The embryo is attached to the placenta by the umbilical cord. The placenta itself is attached to the wall of the uterus. (See figure 14.4.) When the developing embryo begins to take a definite shape it is called a foetus.

While in the uterus the embryo is not breathing; its lungs are not used because oxygen is received through the placenta. However, when the heart develops it begins to beat and circulate the blood, the blood supply of the embryo being quite separate from that of the mother. It is interesting to note that, at this stage, there is a hole in the internal wall of the heart. This hole links the two atria and allows blood to be pumped directly into the aorta without passing through the lungs. The stomach also is closed, the embryo receiving all its nourishment through the placenta directly into its own bloodstream.

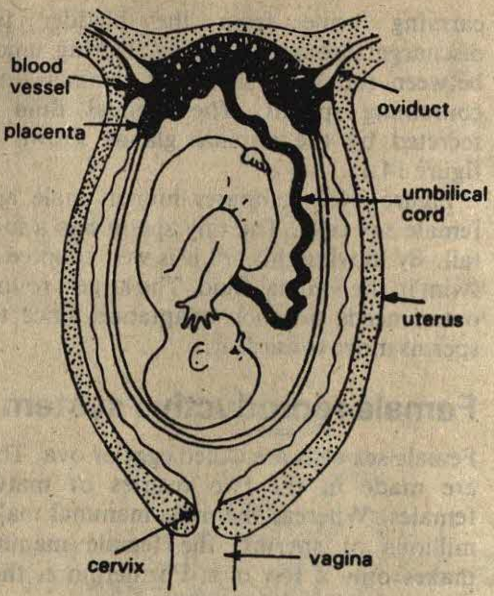


Figure 14.4: A foetus just before birth.

Birth

From the eighth week on, the embryo is called the foetus. At birth, regular contractions of the uterus cause the foetus to be pushed out. The umbilical cord shrinks, thus reducing the supply of food and oxygen to the new-born baby. This also causes an increase in the amount of carbon dioxide in the blood, which is the stimulus causing the commencement of breathing.

When a human baby is born, the umbilical cord is cut and tied. Among most other placental mammals, however, the mother severs the umbilical cord with her teeth.

The heart no longer has a hole in it and the lungs are therefore able to take over the task of absorbing oxygen and excreting carbon dioxide. The stomach, which was previously closed, now opens where it is connected to the oesophagus, and the baby is ready to absorb food. The food comes from the mammary glands of the mother. In the case of human babies, suckling may continue for more than six months. The process of changing from the mother's milk to ordinary food is called weaning.

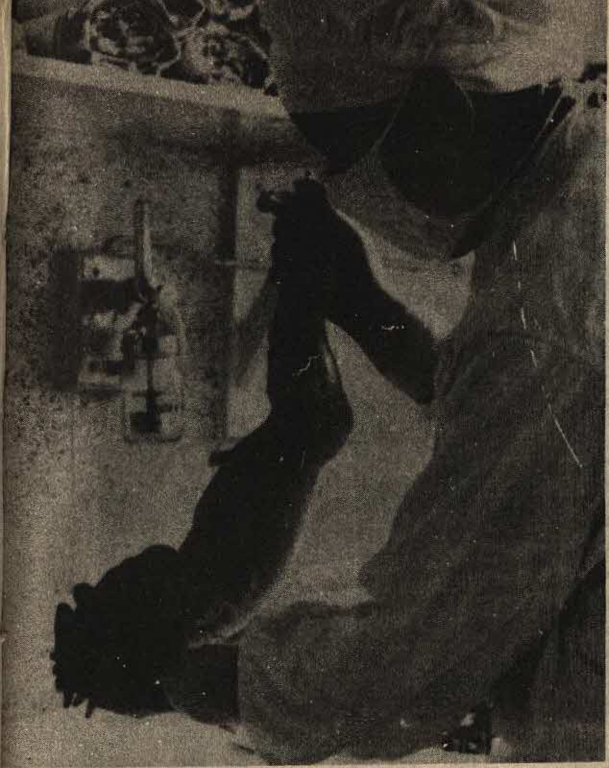


Figure 14.5: A baby a few moments after birth. Notice the umbilical cord, which has been cut and tied.

Growth

One noticeable feature of a new-born human is the shortness of its trunk and limbs compared with its head. (See figure 14.6.) As a baby grows, the rest of its body grows faster than its head.

Children do not grow at a regular rate. The most rapid growth is during the first year of life; growth tapers off after that. However, at about eleven or twelve years of age girls show another increase in rate. This is associated with puberty. The corresponding jump in growth for boys takes place a couple of years later.

Puberty is that time in life when full sexual development occurs. With girls there is enlargement of the breasts, growth of pubic hair and armpit hair and widening of the hips. With boys puberty brings broadening of the shoulders, deepening of the voice and the growth of hair, often over most of the body.

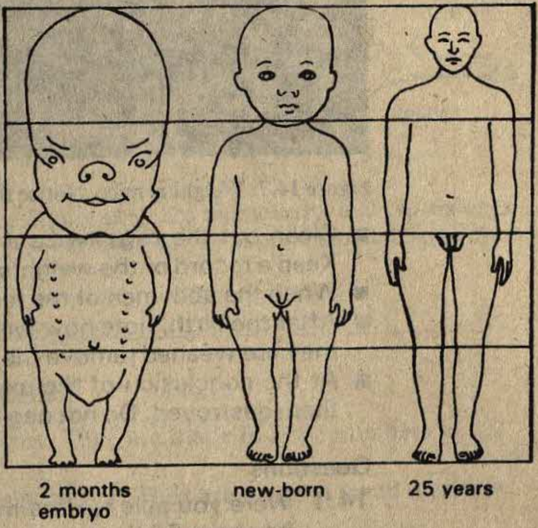


Figure 14.6: Changes in the relative sizes of body parts during growth.

EXPERIMENT *Studying a pregnant mouse*

14.1

Each group will need:

- mouse cage
- sawdust
- shredded paper for nesting
- water container
- special food container
- small wooden block for mice to gnaw
- exercise wheel

What to do

- Select a male and a female mouse.
- Note any special markings that enable you to quickly distinguish between the mice without handling them.
- Place the mice in the cage. Handle them only when necessary.

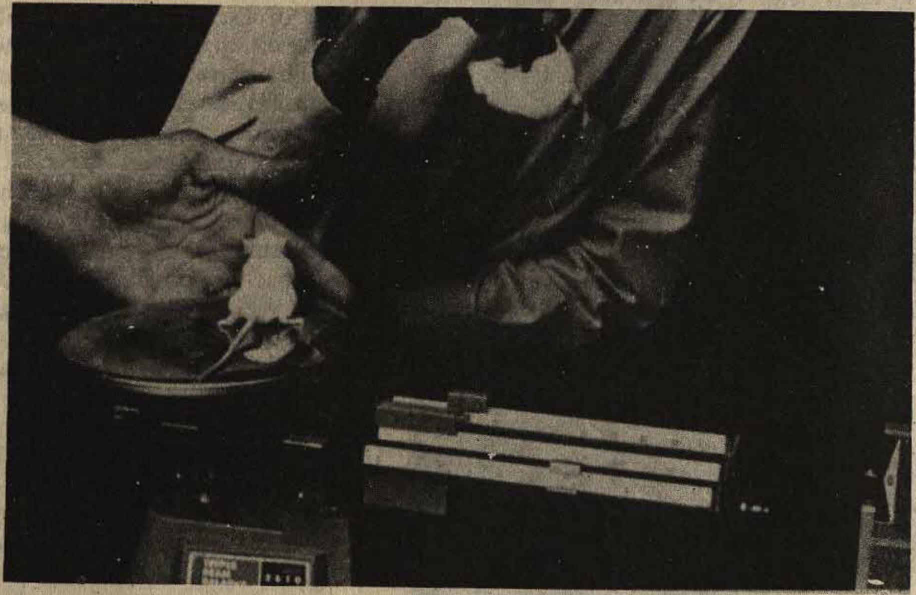


Figure 14.7: Weighing mice. Notice the correct way to pick up a mouse — by the tail.

- Clean out the cage twice a week and at the same time weigh the mice. Keep a record of the weights.
- When the abdomen of the female begins to swell, remove the male.
- After the birth, note how long the young are suckled by the mother. When they are weaned remove them from the cage.
- At the conclusion of the experiment either give your mice away or have them destroyed. Do not neglect them.

Questions

14.1 Were you able to determine the period of gestation of mice? It should be about 20 days.

14.2 Draw a time-weight graph for the female mouse. Does the graph have any interesting features?

EXPERIMENT 14.2

Studying the reproductive organs of a male and a female rat

Each group will need:

- a preserved female and male rat, dissected to show the reproductive organs

What to do

- Refer to figures 14.8 and 14.9.
- Identify in the preserved rats the organs labelled in the diagrams.

Question

14.3 Is there any difference in structure between the uterus of a rat and that of a woman?

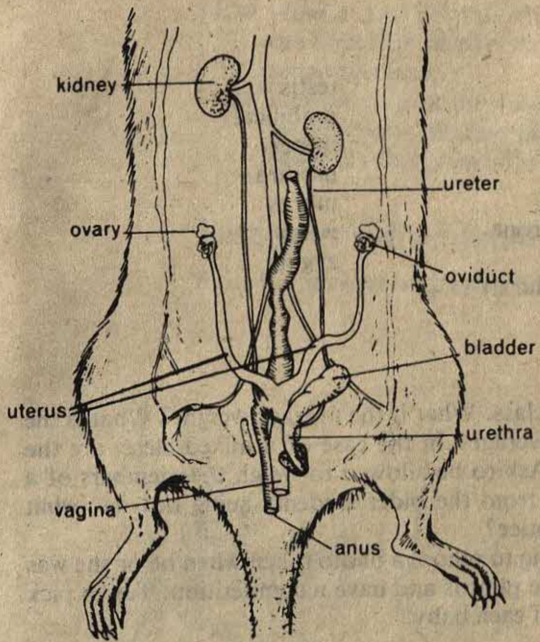


Figure 14.8: The reproductive and urinary organs of the female rat. Veins are omitted to simplify the diagram.

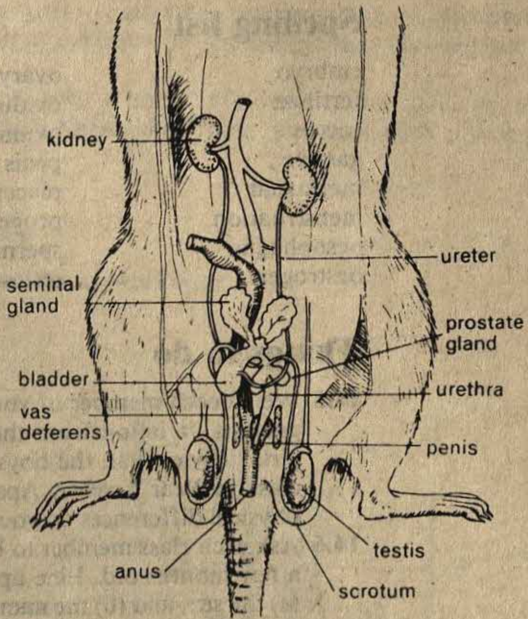


Figure 14.9: The reproductive and urinary organs of the male rat. Veins are omitted to simplify the diagram.

Reproduction in mammals

- Male gametes are called sperms. They are made in large numbers in the testes.
- Female gametes are called eggs or ova. They are made in small numbers in the ovaries.
- A mature ovum is released from one of the ovaries each cycle (approximately once a month in women).
- Mating results in sperms entering the vagina of the female.
- Fertilization occurs when a sperm penetrates an ovum. It usually occurs in the oviducts.
- The fertilized ovum is called a zygote. The zygote develops into the embryo.
- As part of a female's regular menstrual cycle, her uterus is prepared to receive the embryo if fertilization occurs.
- The embryo grows in the uterus of the mother.
- If the ovum has not been fertilized, it breaks down and is shed, along with the special lining of the uterus.
- The placenta is the organ that allows nutrients to pass from the mother to the embryo.
- The embryo develops into the foetus.
- Birth is the expulsion and detachment of the foetus from the mother.

Spelling list

embryo
fertilize
foetus
gamete
menstrual
menstruation
oesophagus
oestrogen
ovary
oviduct
ovum
penis
placenta
progesterone
sperm
testes (plural)
testis
umbilical
ureter
urethra
uterus
wean
zygote

Things to do

14.5 Weigh each member of your class. What is the average weight? What is the greatest variation from the average? In the case of a mixed class, are the girls heavier than the boys? Ask to be allowed to weigh the members of a class in Year Twelve. Apart from the older students being heavier, what physical differences do you notice?

14.6 Ask each class member to bring to school a photo taken when he or she was a few months old. Line up the photos and have a competition. Try to pick (a) the sex, and (b) the name of each baby.

More questions

14.6 What is a placental mammal? What other sorts of mammals are there?

14.7 Describe the differences between the male gametes and the female gametes of a placental mammal. Discuss
(a) shape and size
(b) number produced
(c) ability to move.

14.8 List the reproductive organs of a male placental mammal and describe the function of each.

14.9 List the reproductive organs of a female placental mammal and describe the function of each.

14.10 Why does menstruation occur in female placental mammals?

14.11 What is meant by the term "gestation period"?

14.12 What is the function of the amniotic fluid in the uterus of a placental mammal? (R)

14.13 What is the function of the umbilical cord in a placental mammal?

14.14 What is asexual reproduction? Compare it with sexual reproduction. Discuss (a) the number of parents in each case, (b) the possibility of variety in the offspring in each case.

14.15 What are secondary sexual characteristics? List some. How are these controlled? (R)

14.16 What is a "blue" baby? (R)

14.17 Can a child have blood of a different group from that of its mother? Explain. (R)

14.18 What are identical twins? How do they occur? Are there any other kinds of twins? How do they occur?

14.19 What kind of birth is a breech delivery? (R)

14.20 Have a class debate. Are the girls in your class more mentally mature than the boys? Be sure to state your evidence. If you believe they are, can you suggest a reason?

14.21 How many girls do woodwork jobs at home? How many boys cook? Note the reactions of class members when asked these questions. Can you account for these reactions?

Test yourself (chapter 14)

Write the answers to questions 1 to 4 in your workbook.

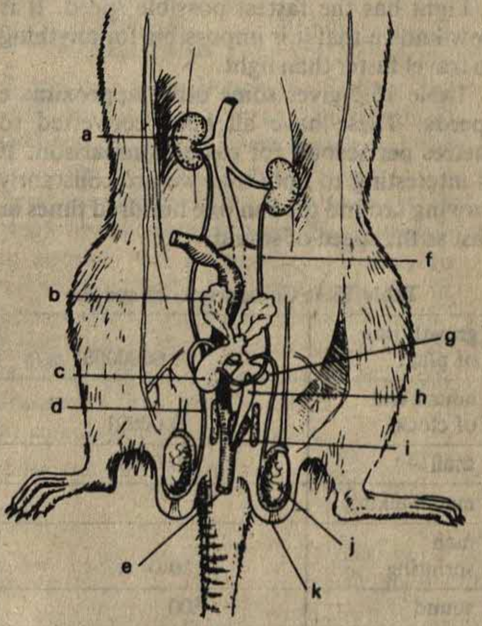


Figure 14.10

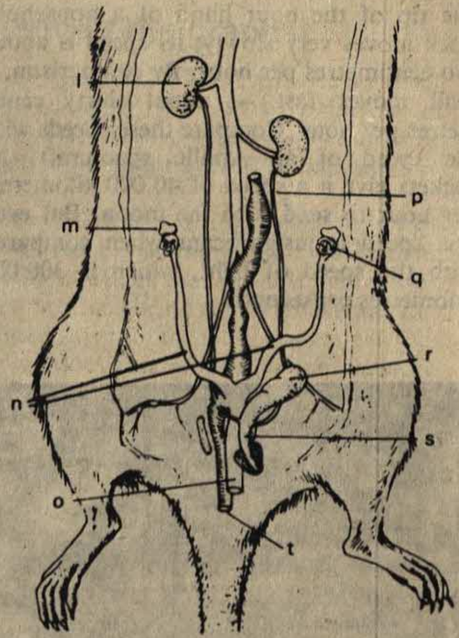


Figure 14.11

1. Figures 14.10 and 14.11 are diagrams showing the reproductive organs of the male and female rat. Name the organs that are labelled a, b, c, etc.
2. Name the organ through which the foetus is nourished in the uterus.
3. When does a baby's heart first begin to beat — while in the uterus or after the baby is born?
4. When do a baby's lungs begin to function?

Choose the best answer to question 5 and write its letter in your workbook.

5. Fertilization usually takes place in the
   - (a) ovary
   - (b) oviduct
   - (c) uterus
   - (d) vagina.

15

Speed and acceleration

The tip of the hour hand of a household clock moves very slowly; its speed is about two centimetres per hour. By comparison, a snail moves fast — about thirty centimetres per hour. Compare these speeds with the speed of an Apollo spacecraft. Its rockets give it a speed of 40 000 kilometres per hour to send it to the moon. But even this speed is insignificant when compared with the speed of light, which is 300 000 kilometres per second.

Figure 15.1: One of the fastest women runners in Australia. Debbie Wells finishing a 100 metre sprint in 12 seconds. (Photo courtesy News Ltd)

Light has the fastest possible speed. It is now known that it is impossible for anything to travel faster than light.

Table 15.1 gives some other approximate speeds. These have all been converted to metres per second for easier comparison. It is interesting to note that we are constantly moving around the sun one hundred times as fast as the speed of sound.

Table 15.1: Comparison of speeds

growth rate of plant	0.00000001 m/s
hour hand of clock	0.00001
snail	0.0001
man walking	1
man sprinting	10
sound	300
Apollo spacecraft	10 000
Earth moving round the sun	30 000
light	300 000 000

Average speed

During our travels, average speed becomes more important than the speed at a particular instant. Knowing the average speed for a journey we can quickly calculate the time for the journey. Here is an example.

A motorist travelled from Bourke to Sydney, a distance of 800 kilometres, in 10 hours. For most of the journey he travelled at 100 km/h. However, he had to reduce this speed when passing through towns. As a result, his average speed for the whole journey was 80 km/h.

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{800\text{ km}}{10\text{ h}}$$
$$= 80\text{ km/h}$$

What would be the estimated time for this motorist to travel from Albury to Sydney, a distance of 580 kilometres?

$$\text{time} = \frac{\text{distance}}{\text{average speed}} = \frac{580\text{ km}}{80\text{ km/h}} = 7\tfrac{1}{4}\text{ h}$$

As in the trip from Bourke to Sydney, the motorist would have to travel at speeds of over 80 km/h on the open sections of the road in order to maintain this average.

There are some interesting answers to problems about average speed. Take the case of an aircraft that travels from Sydney to Auckland, a distance of 2000 kilometres, at a speed of 400 km/h. Suppose the same aircraft makes the return journey at 800 km/h. The average speed is not 600 km/h as might be expected at first, but 533 km/h.

The calculation is as follows.

$$\text{Time for outward journey} = \frac{2000\text{ km}}{400\text{ km/h}}$$
$$= 5\text{ h}$$

$$\text{Time for return journey} = \frac{2000\text{ km}}{800\text{ km/h}}$$
$$= 2\tfrac{1}{2}\text{ h}$$

$$\text{Total distance for round trip} = 4000\text{ km}$$

$$\text{Total time taken} = 7\tfrac{1}{2}\text{ h}$$

$$\text{Average speed} = \frac{4000\text{ km}}{7.5\text{ h}} = 533\text{ km/h}$$

The low average speed is caused by the fact that the aircraft spends more time on the slow outward journey than on the faster return journey.

This example illustrates the fact that average speed is calculated by dividing the total distance by the time taken. It is not calculated by averaging speeds recorded during the journey.

Distance-time graphs

Look at figure 15.1. There you see a runner just finishing a 100 metre sprint in 12 seconds. Her average speed works out to be 8.3 metres per second or 30 kilometres per hour.

Figure 15.2A is a distance-time graph of this run. Note that the graph is a straight line. This indicates that the 100 metres was covered at a uniform rate. We have already calculated this rate to be 8.3 metres per second. But does this graph give an accurate picture of the run? Would the runner be going at full speed the instant after the starting pistol sounded? And wouldn't she make an extra spurt at the finish? Figure 15.2B is a graph that shows a runner gathering speed at the start and finishing with a spurt. Figure 15.2C shows a runner who is tiring and slowing down at the finish.

You might like to test yourself and your group on a 200 metre walk to see if you

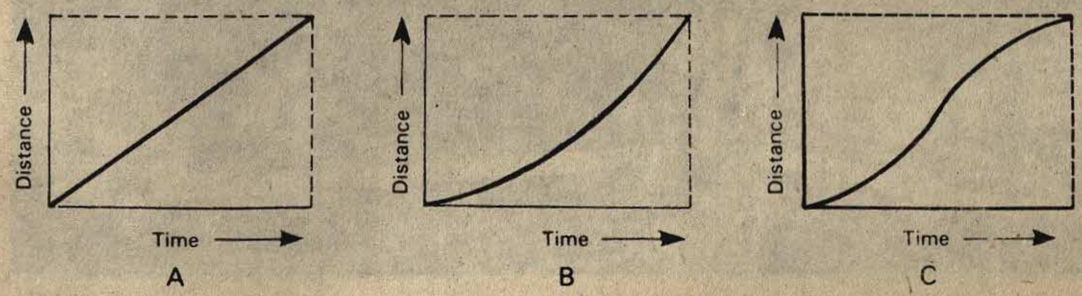


Figure 15.2: A 100 metre sprint. A — covering the distance at uniform speed. B — gathering speed over the whole distance. C — gathering speed at the beginning and fading at the finish.

maintain a uniform speed over the whole distance. The way to do this is explained in experiment 15.1.

Using a ticker-timer

The ticker-timer is an electric vibrator. The one shown in figure 15.3 contains an electromagnet and a make-and-break contact. It works on the same principle as an electric bell. When an electric current flows through it, it vibrates at a regular rate. It is designed so that it makes a dot every time the vibrator strikes the paper strip.

Figure 15.4 shows three tapes made on the timer. Both A and B were pulled through at a uniform speed, tape B at twice the speed of A. Tape C shows the speed increasing.

Tapes of this kind can be used to compare speeds. They can also be used to construct speed-time graphs. Graph A in figure 15.5 is a speed-time graph made by cutting tape A into five-dot sections and pasting the sections on paper to make a column graph. Notice that the tops of the strips make a line

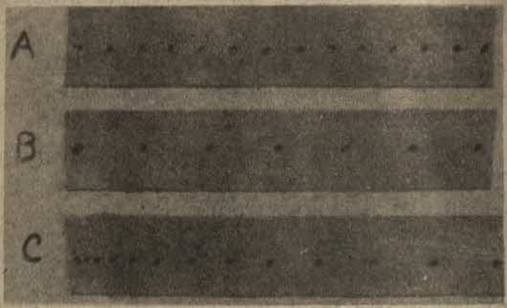


Figure 15.4: Three tapes from a ticker-timer. In tape A the dots are equally spaced. This shows the tape was pulled through the timer at a uniform speed. In tape B the speed is also uniform, but it is twice that of A. Tape C was pulled through slowly at first but with the speed steadily increasing.

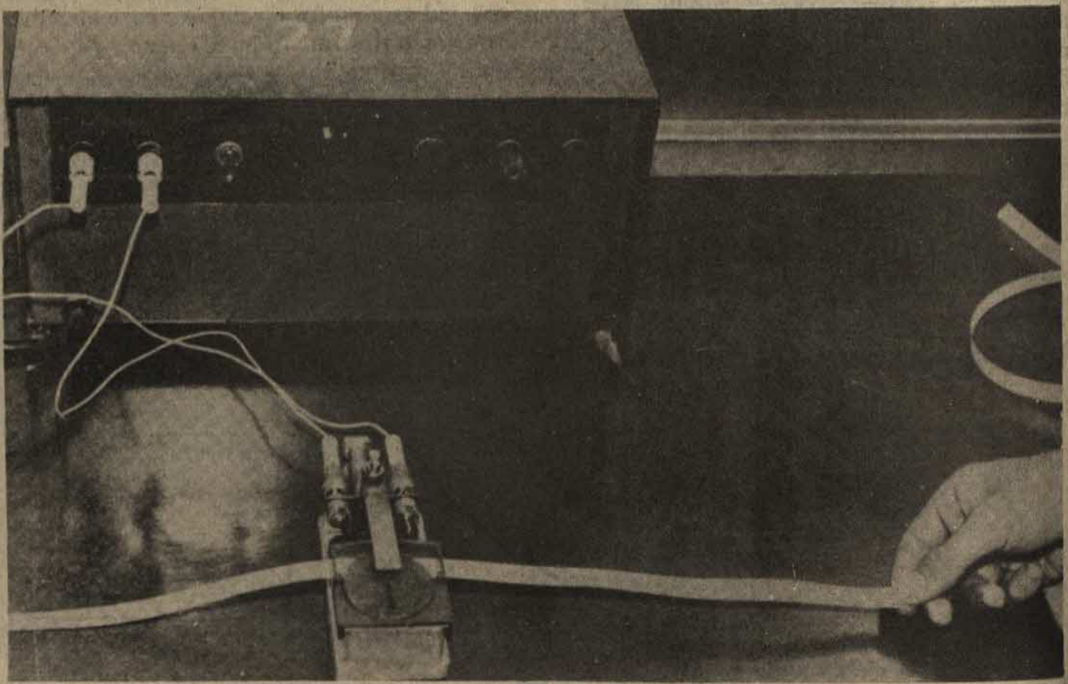


Figure 15.3: Pulling a paper tape through a ticker-timer. The timer hits the tape at regular intervals, making a series of dots. If the tape is pulled through at a steady speed the dots are equally spaced. If the speed is increased, the space between the dots is also increased.

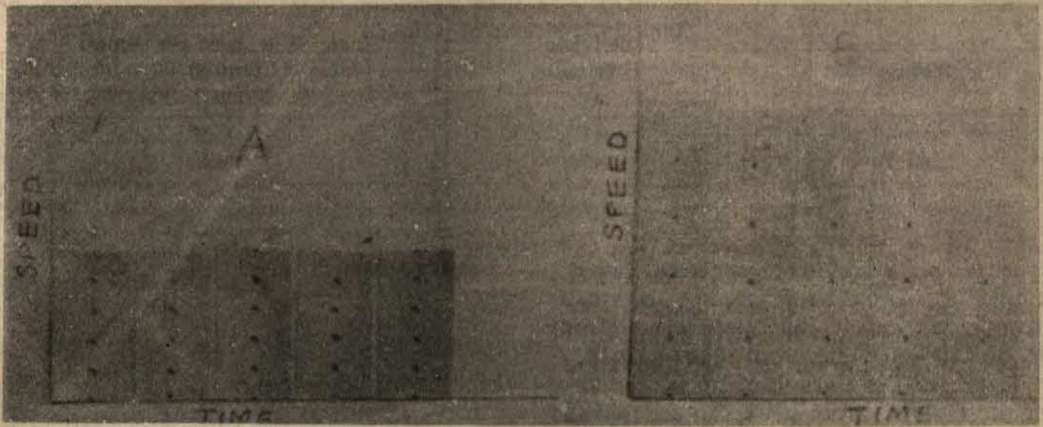


Figure 15.5: Making speed-time graphs from ticker-tapes. The tape is cut up into five-dot segments. The longer these segments the greater is the speed. In both graphs the speed is uniform, but the speed in B is twice that of A.

parallel to the base. This indicates that the speed is uniform.

Graph B in figure 15.5 is a graph of tape B prepared in the same way as graph A. Because the speed of tape B is twice that of A, the strips are twice as tall as those in A.

Acceleration

In tape C (figure 15.4), the speed is increasing. We say the tape is accelerating as it is pulled through the timer. If we cut this tape into five-dot pieces we find each successive piece is longer than the previous one. When the pieces are put together as a column graph we get the result shown in figure 15.6.

The tops of the columns in figure 15.6 make a straight line. This indicates that the speed is increasing at a regular rate. In other words, the acceleration is uniform.

When a new model of car is introduced, motorists are often interested in its acceleration figures. They want to know what its "pick-up" is like. Table 15.2 gives some information about the acceleration of a type of Honda car.

These figures show that the Honda's acceleration is better at low speeds than at high

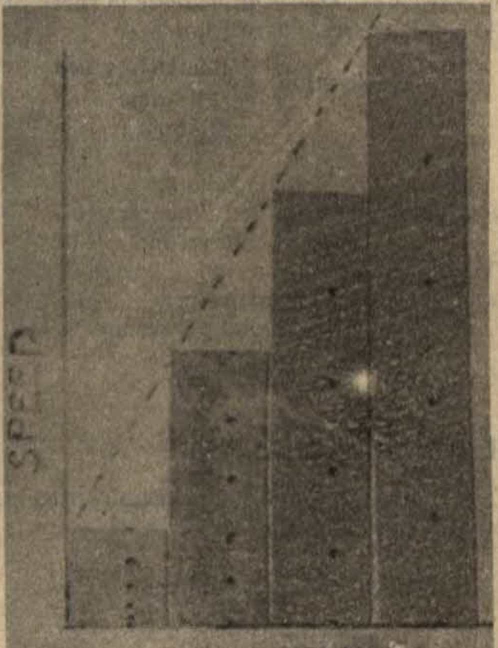


Figure 15.6: A speed-time graph showing acceleration. Here the graph is a straight line, which shows that acceleration is uniform.

Table 15.2: Pick-up of a Honda

Speed increase (km/h)	Time taken (s)	Increase in speed per second (km/h)
0–40	3	13.3
40–70	5	6.0
70–100	8	3.8

speeds. This is only to be expected. For example, if a car has a top speed of 180 km/h, it would take much longer to accelerate from 150 to 180 km/h than from 10 to 40 km/h.

Figure 15.7 is a graph of the acceleration of the Honda. From it we can see that the greater the acceleration, the steeper is the line that represents it.

Calculating acceleration

Referring to table 15.2, we see that the car increased its speed from 40 km/h to 70 km/h in 5 seconds. This is an increase in speed of 30 km/h in 5 seconds or 6 km/h/s.

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time}} = \frac{30\text{ km/h}}{5\text{ s}} = 6\text{ km/h/s}$$

Remember, 6 km/h = 1.7 metres per second

Therefore,

acceleration = 1.7 metres per second per second

$= 1.7\text{ m/s/s}$

$= 1.7\text{ m/s}^2$

Equations of motion

The following symbols are generally used in writing equations of motion.

t = time interval

u = speed (velocity) at beginning of time t (also called "initial velocity")

v = speed (velocity) at end of time t

a = acceleration

s = distance travelled in time t

The equations of motion are built up from simple beginnings:

Change in speed $= v - u$

$$\text{Acceleration} = \frac{\text{change in speed}}{\text{time}}$$

$$a = \frac{v-u}{t}$$

Multiplying both sides by t,

$$at = v - u$$

$$v = u + at \text{ ..... } \textit{Equation 1}$$

Example. Suppose a car travelling at 8 m/s accelerates uniformly at 2 m/s² for 5 seconds. How fast is it travelling at the end of the 5 seconds?

$u = 8\text{ m/s}$

$v = ?$

$t = 5\text{ s}$

$a = 2\text{ m/s}^2$

$v = u + at$

$= 8 + 2 \times 5 = 18\text{ m/s}$

Finding a second equation

Look at figure 15.8. Graph A shows a car travelling at a uniform speed of 2 m/s for 6 seconds. Graph B shows a car accelerating from 0 m/s to 4 m/s in 6 seconds. In both graphs the shaded areas are equal. But the shaded areas represent the distance travelled in 6 seconds. Therefore the distances travelled by the two cars are equal.

Distance travelled by car A $= 2 \times 6$

$\doteq 12\text{ m}$

Average speed of car B $= \frac{0+4}{2}$

$= 2\text{ m/s}$

Distance travelled by car B $= 2 \times 6$

$= 12\text{ m}$

From this we can derive an equation.

Provided a car is accelerating at a steady rate,

distance travelled = average speed × time

$$s = \frac{u+v}{2} \times t \text{ .... } \textit{Equation 2}$$

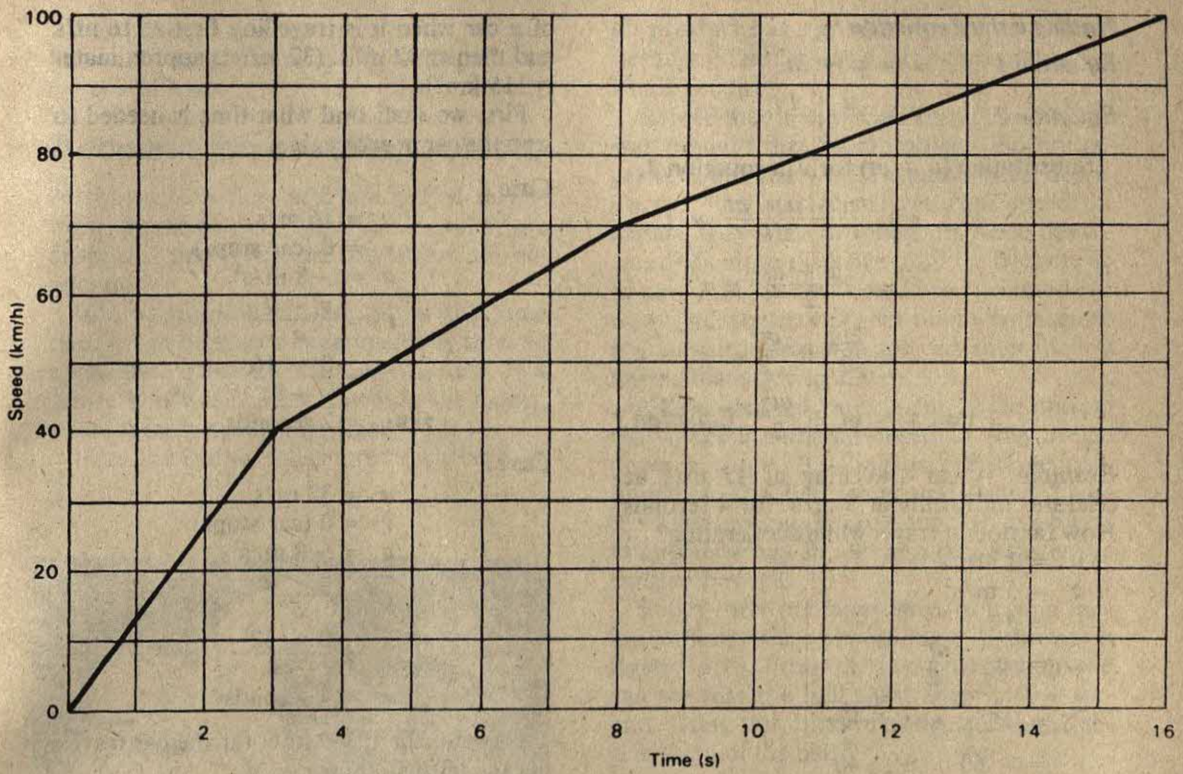


Figure 15.7: Graph of the pick-up of a Honda car over various ranges of speed.

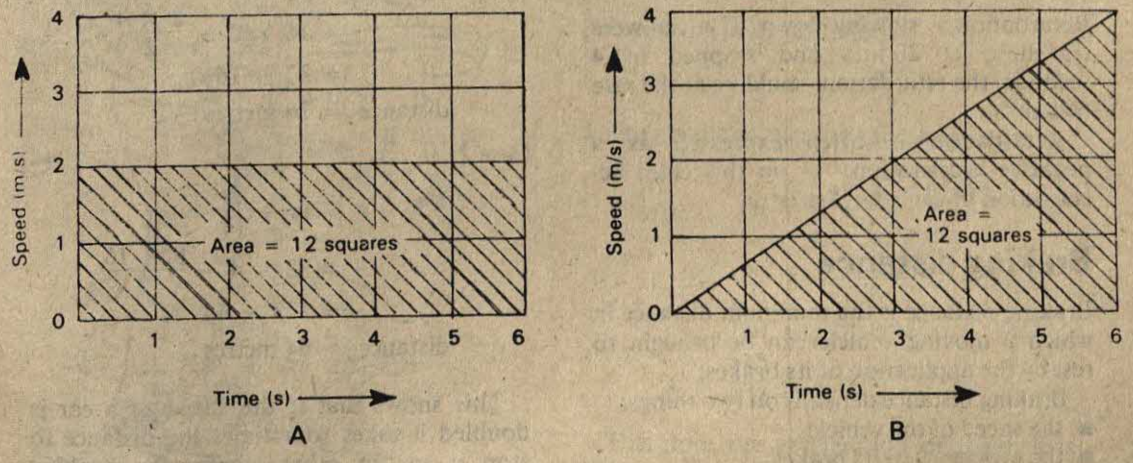


Figure 15.8: Using speed-time graphs to calculate distance. The area of each square represents 1 metre — the distance travelled in 1 second at a speed of 1 metre per second. The shaded areas in both graphs are equal and represent a distance of 12 metres. This shows that a car accelerating from 0 m/s to 4 m/s in 6 seconds covers the same distance as a car travelling for 6 seconds at 2 m/s.

Finding a third equation

Equation 1 .... $v = u + at$

Equation 2 .... $s = \frac{u + v}{2} \times t$

Substituting $(u + at)$ for v in equation 2,

$$
\begin{aligned}
s &= \frac{u + u + at}{2} \times t \\
&= \frac{2u + at}{2} \times t \\
&= \frac{2ut}{2} + \frac{at^2}{2}
\end{aligned}
$$

i.e., $s = ut + \frac{at^2}{2}$ ... *Equation 3*

Example. A car travelling at 15 m/s accelerates uniformly at 5 m/s^2 for 4 seconds. How far does it travel while accelerating?

$$
\begin{aligned}
u &= 15\ \text{m/s} \\
a &= 5\ \text{m/s}^2 \\
t &= 4\ \text{s} \\
s &= ut + \frac{at^2}{2} \\
&= 15 \times 4 + \frac{5 \times 4^2}{2} \\
&= \quad 60 \quad + \quad 40 \\
&= 100\ \text{metres}
\end{aligned}
$$

Retardation or deceleration

Retardation is slowing down. If a car were travelling at 20 m/s and stopped in 4 seconds, the retardation would be at the rate of 5 m/s^2.

Retardation is often expressed as a negative acceleration. ∴ in this case, acceleration of car = $-5\ \text{m/s}^2$

Braking distance

Braking distance is the minimum distance in which a moving vehicle can be brought to rest by the application of its brakes.

Braking distance depends on two things:

- the speed of the vehicle
- the efficiency of its brakes.

Tests show that the average deceleration of a car is about 8 m/s^2, provided the brakes are in good condition.

Let us now compare the braking distances of a car when it is travelling first at 16 m/s and then at 32 m/s. (32 m/s is approximately 115 km/h.)

First we shall find what time is needed to stop the car in each case.

Case 1

$$
\begin{aligned}
u &= 16\ \text{m/s} \\
v &= 0\ \text{(car stops)} \\
a &= -8\ \text{m/s}^2 \\
t &= \frac{v - u}{a} \\
&= \frac{0 - 16}{-8} \\
\text{time} &= 2\ \text{seconds}
\end{aligned}
$$

Case 2

$$
\begin{aligned}
u &= 32\ \text{m/s} \\
v &= 0\ \text{(car stops)} \\
a &= -8\ \text{m/s}^2 \\
t &= \frac{v - u}{a} \\
&= \frac{0 - 32}{-8} \\
\text{time} &= 4\ \text{seconds}
\end{aligned}
$$

Now we shall find how far the car travels in each of these times.

Case 1

$$
\begin{aligned}
s &= ut + \frac{at^2}{2} \\
&= 16 \times 2 - \frac{8 \times 4}{2} \\
&= 32 - 16 \\
\text{distance} &= 16\ \text{metres}
\end{aligned}
$$

Case 2

$$
\begin{aligned}
s &= ut + \frac{at^2}{2} \\
&= 32 \times 4 - \frac{8 \times 16}{2} \\
&= 128 - 64 \\
\text{distance} &= 64\ \text{metres}
\end{aligned}
$$

This shows that if the speed of a car is doubled it takes four times the distance to stop it in. In other words, the braking distance is proportional to the square of the speed. If you increase your speed three times, you need nine times the distance to stop.

Inexperienced drivers very often do not know this fact; ignorance of it is the cause of many accidents.

Acceleration of falling objects

All objects on the earth are pulled downwards by the force of gravity. When they are dropped, this force causes them to accelerate.

In a vacuum all objects fall at the same rate. It can be shown experimentally that, in a vacuum, a feather falls just as fast as a stone. This was demonstrated on the moon, where there is no air. (See figure 15.9.)

In air the feather falls more slowly because air pressure has a greater effect on it. This is because a feather has a large area and a very small weight.

Figure 15.9: Famous experiment carried out by the Apollo 15 moon mission. The hammer and the feather fall at the same rate. This happens because there is no atmosphere on the moon.

Before the time of Galileo (1564–1642), it was thought that falling objects did not accelerate but fell with a steady speed downwards. They started off with this speed the instant they were dropped. In those days it was difficult to disprove this idea because no accurate timing device had been invented. As well, philosophers of that time were keen to put forward ideas but not very interested in testing them by experiment.

Galileo was an experimenter. He noticed that objects gathered speed as they rolled down a slope. So long as the slope continued, they rolled faster and faster. From this observation he reasoned that objects falling vertically should also move faster the further they fell.

Today there are many ways of timing falling objects. One simple way is shown in figure 15.10. From the two photographs we can see that the ball falls 80 cm in 0.4 second. Using this data we can calculate the acceleration of the ball.

$$\begin{aligned} \text{time } (t) &= 0.4 \text{ s} \\ \text{initial velocity } (u) &= 0 \text{ cm/s} \\ \text{drop } (s) &= 80 \text{ cm} \end{aligned}$$

Substituting in the equation,

$$s = ut + \frac{gt^2}{2},$$

where g is the acceleration due to gravity,

$$80 = 0 + \frac{g \times (0.4)^2}{2}$$

$$80 = \frac{g \times 0.16}{2}$$

$$160 = g \times 0.16$$

$$g = \frac{160}{0.16} = 1000$$

Therefore the acceleration of the ball is 1000 cm/s^2, or 10 m/s^2.

Experiments like this have been done many times. Results obtained from more accurate equipment indicate that the acceleration of a falling object is 9.8 m/s^2.

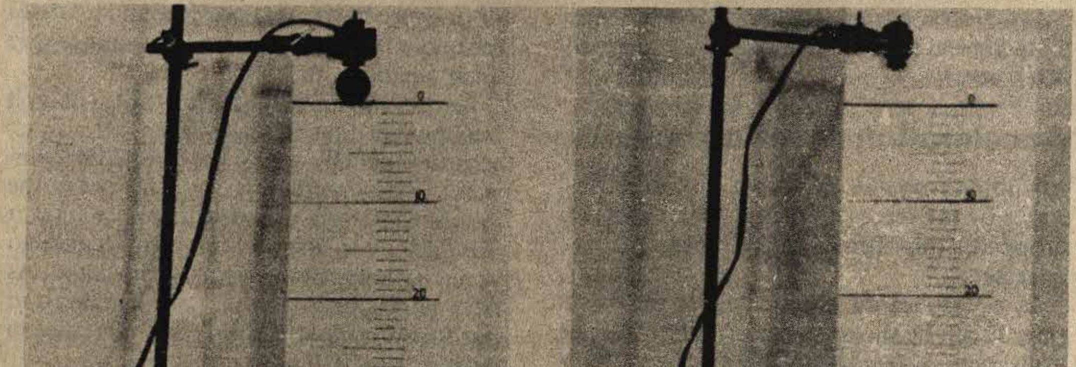


Figure 15.10: Finding the acceleration of a falling iron ball. The photo on the left shows the ball held by an electromagnet. It is released by pressing a switch. The same switch starts the clock. The photo on the right was taken while the ball was falling.

Gravity on the moon and other planets

The pull of gravity on other members of the solar system can be calculated if the mass and size of the moon or planet are known. The greater the mass, the stronger the pull of gravity on its surface. The size also affects the pull. If two planets are equal in mass, the smaller one exerts a stronger pull on objects on its surface.

Table 15.3 gives the accelerations of falling objects on some planets and the moon.

Table 15.3: Gravity on the moon and some planets

	Acceleration due to gravity	Equivalent weight of 60 kg person
Earth	9.8 m/s^2	60 kg
Moon	2.0 ”	10 ”
Mars	3.6 ”	22 ”
Jupiter	24.8 ”	152 ”
Saturn	10.5 ”	64 ”

Gravity on the moon is only about one-sixth of what it is on earth. Therefore, a 90 kg pack carried by a member of the Apollo team on the moon weighed the same as a 16 kg pack carried on the surface of the earth. Another effect is that on the moon a stone falls approximately 80 metres in 9 seconds whereas on the earth it takes only 4 seconds to fall the same distance. (See question 15.20.)

EXPERIMENT

15.1

Can you keep up a constant pace when walking 200 metres?

Each group will need:

- 25 metre tape
- stopwatch
- 4 wooden pegs
- hammer

What to do

- In your school grounds, measure out a square with each side 25 metres long. Drive in a peg at each corner.
- Walk 200 metres by going around the square twice. In walking, the heel must touch the ground first each time the foot comes down.
- Have the timekeeper and the recorder in the centre of the square.
- Press the watch when each walker starts and read aloud the times as the walker makes each turn. Time to within 0.1 of a second, if possible. Record the times in a table in your notebook.

Walker	Times for							
	25 m	50 m	75 m	100 m	125 m	150 m	175 m	200 m

Questions

15.1 Have each person draw his or her own distance-time graph.
15.2 Write a conclusion explaining the results.

EXPERIMENT

15.2

What is the acceleration of a freely falling stone?

Each group will need:

- ten spherical stones about 250 g each
- stopwatch
- length of cord

What to do

- Obtain a number of stones as nearly spherical as possible.

- Select a window three or four storeys from the ground.
- Drop the stones one at a time from the window and time their fall to the ground. It is difficult to anticipate the moment when a person holding a stone opens his hand and allows it to fall. To overcome this problem, place the stone on a fixed board that projects out of the window. Knock the stone off the board by making a long sweep with a stick. The person holding the watch can then anticipate the moment the stick makes contact with the stone.
- Work out the average of the times the stones take to fall.
- Measure the distance the stones fall by using a long thread with a sinker tied to one end.
- Calculate the acceleration downwards by using the equation

  $s = ut + \frac{at^2}{2}$.

  But $u = 0$.

  Therefore this equation becomes

  $s = \frac{gt^2}{2}$, where g is the acceleration due to gravity.

Questions

15.3 Why is it preferable to use spherical stones?

15.4 The time of fall is very short. Therefore, a small error in recording the time becomes a large fraction of the time of fall. Can you suggest ways of reducing this fraction?

15.5 What value did you obtain for the acceleration? How does it compare with the accepted value?

EXPERIMENT

15.3

Timing a ball-bearing rolling down a grooved track

Each group will need:

- large ball-bearing
- grooved track, such as a length of smooth angle iron, about 3 metres long
- stopwatch
- blocks of wood

What to do

- Set up the track on a slope so that the ball-bearing rolls down the length of it in about 6 seconds. Fix the track in position with plasticine or clamps.
- Mark a starting point at the top of the slope.
- Allow the ball to roll down the slope. Mark the point it reaches in 1 second.
- Do this 5 times and then estimate the average distance the ball travels in 1 second.
- Similarly, find the distance the ball travels in 2, 3 and 4 seconds.
- Tabulate your results.

Elapsed time, t (s)	Distance travelled, s (cm)	t^2
1 2 3 4		

Question

15.6 Did you find that the distance the ball rolls is proportional to the elapsed time squared? This means that the ball rolls 4 times as far in 2 seconds as it does in 1 second; in 3 seconds it rolls 9 times as far, and so on.

Speed and acceleration

- Average speed $= \dfrac{\text{distance travelled}}{\text{time}}$
- Acceleration $= \dfrac{\text{change of speed}}{\text{time}}$
- Three equations of motion are:

$$v = u + at$$

$$s = \frac{u + v}{2} \times t$$

$$s = ut + \frac{at^2}{2}$$

- If the speed of a car is doubled, it needs four times the distance to stop.
- An object falls four times as far in two seconds as it does in one second.

Spelling list

acceleration
deceleration
Galileo
kilometre
retardation

Things to do

15.7 Using a ticker-timer, compare the acceleration of a trolley down slopes of different steepness. Compare tapes for slopes that fall from heights of 10 cm and 20 cm. Make two column graphs in the same way as was described on page 171. What do you notice about the graphs?

15.8 Measure the speed of sound by standing about 50 metres in front of a large brick wall and banging a metal drum with a hammer at a regular rate. Change the rate until you hear "bang-echo-bang-echo", etc. Then record the time for 21 bangs. Divide by 20 to obtain the time interval between two successive bangs. Divide again by 2 to find the time it takes the sound to go to the wall and return.

15.9 How did early scientists time their experiments? Remember that stopwatches were unknown at the time of Galileo. Refer to your library to find the answer.

More questions

(Answers to questions involving calculation are given in appendix 2.)

15.10 A man rows across a river 2 km wide at 8 km/h. He picks up some people and returns at 4 km/h. Calculate:
(a) the time taken to cross the river the first time
(b) the time taken to return
(c) the average speed for the 4 kilometres.

15.11 A car starts from rest. Its speed at each second afterwards is as follows:

Time (s)	Speed (m/s)
0	0
after 1	2
" 2	4
" 3	6
" 4	8
" 5	9
" 6	10
" 7	11
" 8	12

(a) Is the car moving with a steady speed?
(b) Is the car accelerating?
(c) If it is, is the acceleration steady?
(d) What is the acceleration over the first 4 seconds?
(e) What is the acceleration over the final 4 seconds?

15.12 Two cars travel the same journey. The distance is 160 kilometres. One car averages 40 km/h; the other 80 km/h. Represent these two journeys on the one sheet of graph paper. Graph distance against time.

15.13 A car travels 120 kilometres at 60 km/h. It stops for half an hour and then travels 200 kilometres at 100 km/h. Represent this journey on a distance-time graph.

15.14 In testing the acceleration of a certain car, a distance of 400 metres was covered in 20 seconds from rest. What was the average speed of the car? Assuming the acceleration to be uniform, what speed was reached in the 400 metre run?

15.15 In a road test, car A accelerated from 0 to 72 km/h in 8 seconds and car B accelerated from 0 to 108 km/h in 10 seconds. Work out the acceleration in each case and compare them. (Note: 36 km/h is exactly 10 m/s.)

15.16 A car accelerated from 0 to 96 km/h in 18 seconds. Assuming the acceleration to be uniform, what were the average speed and the distance travelled in this time?

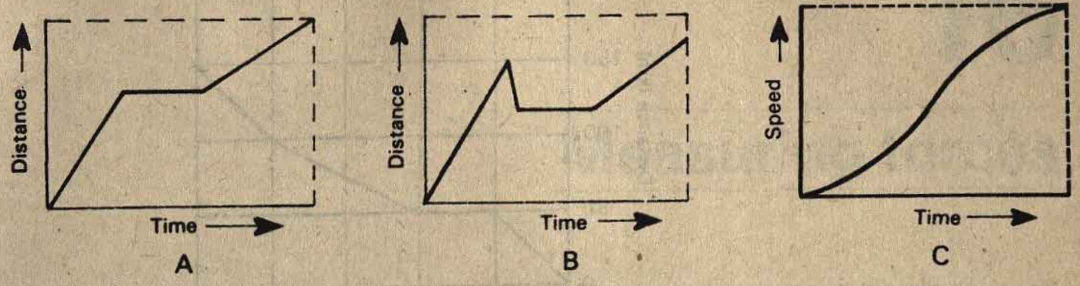


Figure 15.11: A — a journey; B — a ball-game; C — a moving car.

15.17 Refer to the graphs in figure 15.11. Write a short description of what each graph tells you.

15.18 The roadway of the Sydney Harbour Bridge is 55 m above the water. How long does it take a stone to fall from the bridge to the water?

15.19 A car starting from traffic lights accelerates uniformly at 2 m/s^2 for 6 s. It then travels for 10 s at a uniform speed towards the next set of lights. These lights are red and the car stops in 2 s.

Draw a graph of the car's movement, plotting speed against time. Use your graph to estimate the distance between the lights. Use the following scales: horizontal, 1 cm = 1 s; vertical, 1 cm = 1 m/s.

15.20 Calculate and compare the times taken for an object to fall 80 m on the earth and on the moon. Ignore air resistance on the earth and take g on the moon to be 2.0 m/s^2 and on the earth to be 10 m/s^2.

15.21 How far does a lump of lead fall on the earth in (a) 1 s, (b) 2 s, (c) 3 s? Draw a graph plotting distance against time. Use the following scales: horizontal, 5 cm = 1 s; vertical, 1 cm = a distance of 5 m. How far does the lead fall in (d) the first second, (e) the second second, (f) the third second? Take $g = 10\ m/s^2$.

15.22 What is meant by a driver's reaction time? A car is travelling at 18 m/s. If the driver's reaction time is 0.6 s and the brakes produce a deceleration of 8 m/s^2, in what distance can the car be brought to a standstill in an emergency? (Note that the car travels for 0.6 s at 18 m/s before the driver applies the brakes.)

15.23 Why was it necessary to have a huge rocket to send the first Apollo mission to the moon, but a smaller unit to return it from the moon to the earth? (R)

Test yourself (chapter 15)

Write the answers in your workbook.

1. A man rows 5 km down a river at 10 km/h. He rows back at 5 km/h. Calculate his average speed for the double journey.
2. A car is travelling at 20 m/s. It accelerates uniformly to 25 m/s in 4 seconds. Calculate
   (a) the acceleration
   (b) the distance travelled while accelerating.

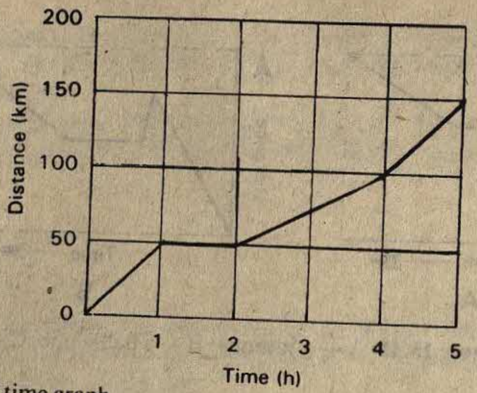


Figure 15.12: A distance time graph.

3. Refer to figure 15.12. This is a distance-time graph for a car. Write down the
   (a) total distance travelled
   (b) average speed for the first hour of the journey
   (c) ,, ,, ,, ,, second ,, ,, ,, ,,
   (d) ,, ,, ,, ,, fourth ,, ,, ,, ,,
   (e) ,, ,, ,, ,, fifth ,, ,, ,, ,,
   (f) average acceleration for the fifth hour.
4. Figure 15.13 is a speed-time graph of a car for 4 seconds.
   (a) Was there any time in the 4 seconds when the car was travelling at a constant speed? If so, when?
   (b) Was there any time when the car's acceleration was constant? If so, when?
   (c) What distance (approximately) did the car travel in the 4 seconds? (Estimate an area by counting the squares.)

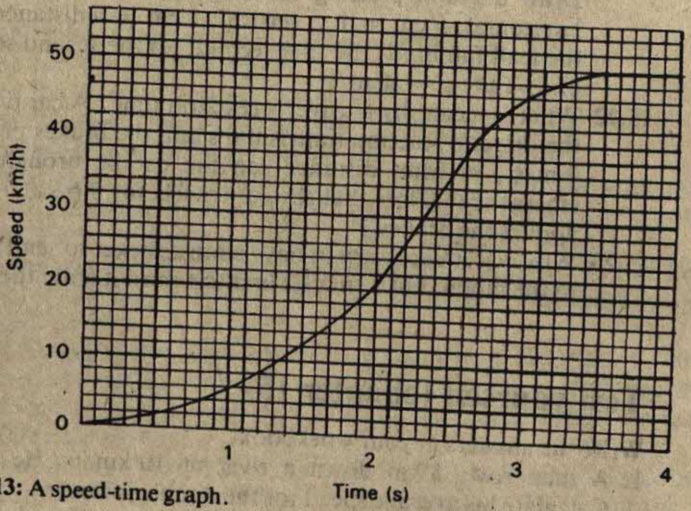


Figure 15.13: A speed-time graph.

5. A driver in a car travelling at 86 km/h sees a child running out on to the road 30 metres in front of him. His brakes can decelerate the car at 8 m/s^2. Can he pull up in less than 30 metres? (Note: 86 km/h = approximately 24 m/s.)

16

Measuring forces

In *Concepts of Science 2* we defined forces as being pushes or pulls. We also mentioned some common forces. These everyday forces act against and sometimes overcome

- inertia — giving things an acceleration
- gravity — lifting things
- friction — overcoming the drag of one object rubbing against another.

Balanced forces

Most objects around you are at rest — for example, the furniture in your home, the books on the shelf, the barrow in the yard.

Although they are at rest, all these objects are acted upon by at least two forces:

- the force of gravity downwards
- the push upwards of the floor or ground on which the object is standing.

These pairs of forces are equal and opposite. We call them action and reaction. The action is the weight force downwards and the reaction is the upward force brought into play to balance it.

Figure 16.1 shows what happens when a person stands on a plank of wood. Wood is elastic, so the plank bends. It is this bending that brings into play the reaction upwards that balances the weight downwards.

It must not be thought that it is only on stationary objects that forces are balanced. The forces acting on a moving object are also balanced if the object is moving at a constant speed in a straight line.

The car in figure 16.2 is an example of an object in this state. It is travelling at a uniform speed. The force forward — exerted by the engine — just balances the force backward — wind resistance and the forces of friction on the road. The weight of the car is balanced by the reaction of the road.

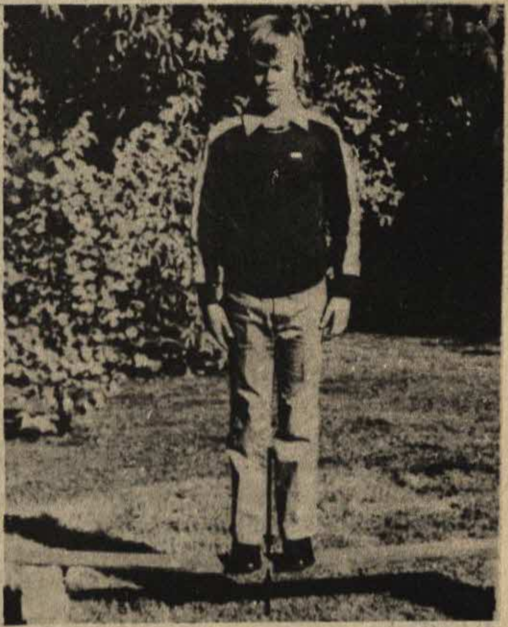


Figure 16.1: An example showing that action and reaction are equal and opposite. The action is the weight of the person acting downwards. The reaction is the upward force brought into play by the elasticity of the wood.

Unbalanced forces

If the driver of the car in figure 16.2 pushes down on the accelerator pedal, the thrust of the engine is increased. The forces are now out of balance and there is a net force forward. This net force causes the car to accelerate. As its speed increases so does air

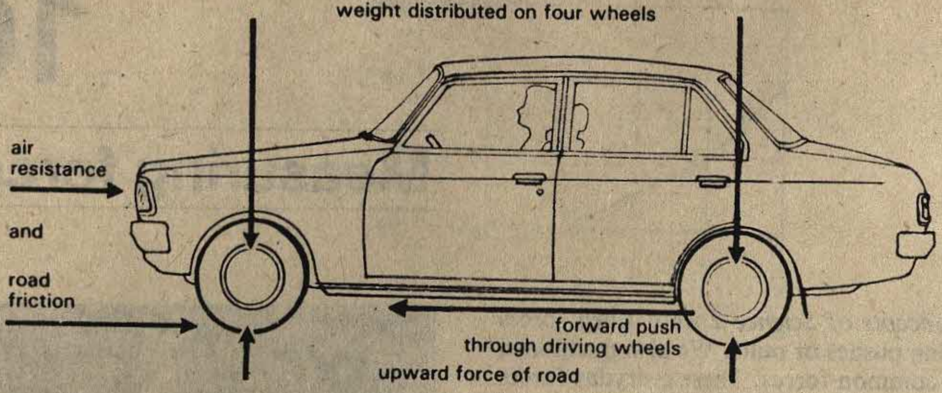

weight distributed on four wheels
air resistance
and
road friction
forward push through driving wheels
upward force of road

Figure 16.2: A car travelling at a steady speed has all forces balanced. The car's weight is supported by the road. The thrust of the engine balances air resistance and road friction.

resistance, until eventually there is a balance again. When this happens the car again moves along at a uniform speed, but this speed is higher than before. If the driver lifts his foot off the accelerator pedal, the thrust of the engine is decreased and there is a net force acting against the car's forward motion. This causes the car to decelerate.

Incidentally, air resistance is approximately proportional to the square of the speed. If you double your speed, air resistance against your car becomes four times as great.

Measuring the effect of a net force

Let us now investigate the effects of forces of different sizes acting on a trolley that is free to move. To do this we use a trolley and a ticker-timer, as shown in figure 16.3. The board or bench on which the equipment is set up is tilted slightly, so that when the trolley is given a small push it runs down the slope at a uniform speed, pulling the tape through the timer. Because the trolley's speed is uniform we know that the slope is enough to balance the forces of friction.

A steady net force is applied to the trolley by pulling on a spring balance attached to it. This is not easy — it is hard to pull steadily on an object moving towards you.

The tape is then removed and cut into 5-dot pieces. Figure 16.4 shows a column graph made from these pieces. Note that the tops of the strips make a straight line. This indicates that the acceleration is uniform. We may therefore conclude that

- *A constant force produces a constant acceleration.*

Next, let us examine the effect of doubling the force we exert on the trolley. Figure 16.4B shows the column graph made from the tape produced when we do this. You can see that the slope of the graph is steeper this time. In fact, the height the second graph reaches is twice that of the first. From this it would appear that

- *Doubling the net force doubles the acceleration.*

This conclusion is borne out by trebling the force, and by multiplying it by four. In all cases,

- *The acceleration of a body is directly proportional to the net force acting on it.*

What effect does changing the mass have on the acceleration produced by a net force?

The mass of the trolley may be increased by placing additional masses on it. Carrying out another experiment in the same way as the others, we find that doubling the mass halves the acceleration produced. If the mass is trebled, the acceleration is reduced to one third, etc. This result may be stated thus:

- *The acceleration produced by a net force is inversely proportional to the mass of the body.*

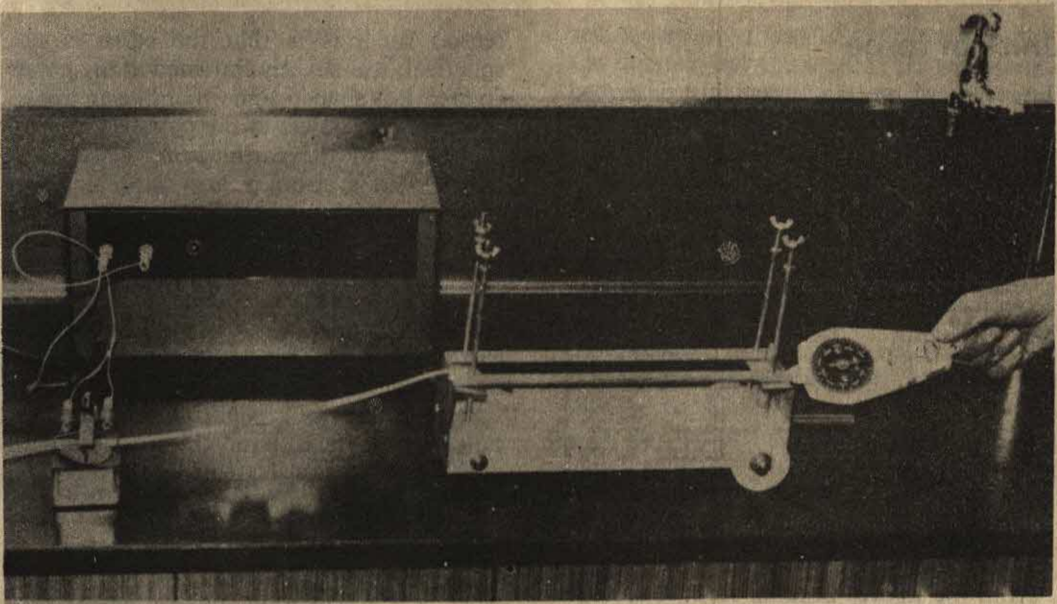


Figure 16.3: Pulling a trolley with a steady force. This causes it to accelerate and the dots on the tape to b spaced further and further apart.

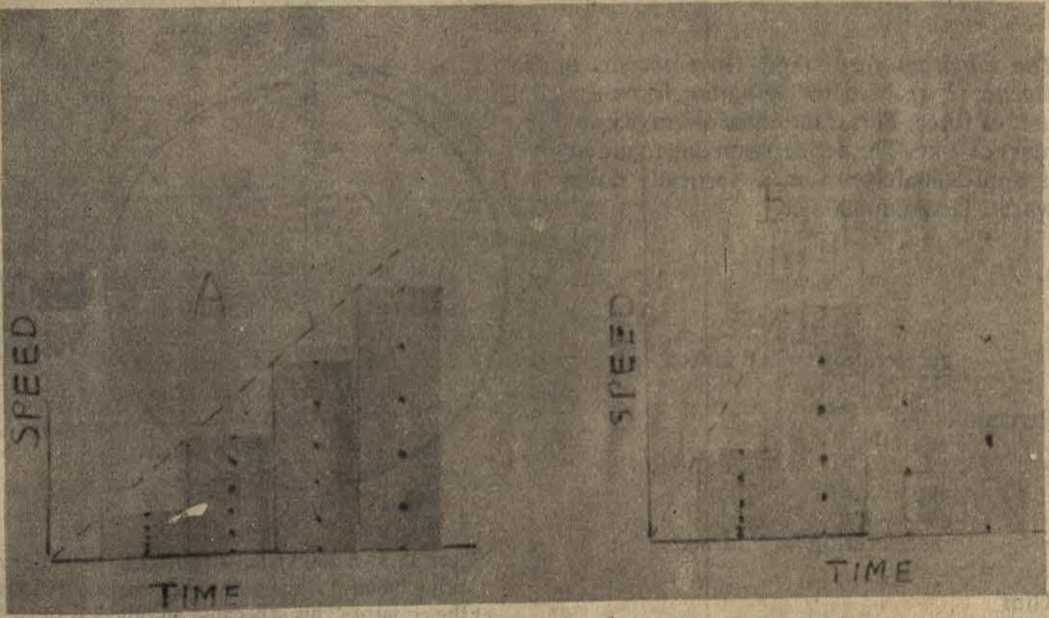


Figure 16.4: Two column graphs made by cutting the tapes into five-dot strips. Graph A is the result when a steady force acts on the trolley. Graph B shows the result when this force is doubled. The slope of graph B is twice as steep as the slope of graph A.

Units of force

The results of the experiment just described allow us to define a unit of force as that force that causes a mass of 1 kilogram to accelerate at 1 metre per second per second. Such a force is called 1 newton (1 N).

Table 16.1: Effect of net force on a mass

Net force acting (N)	Mass moved (kg)	Acceleration produced (m/s^2)
1	1	1
2	1	2
3	1	3
6	2	3
9	3	3
42	7	6

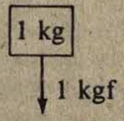
From the figures in table 16.1 we can see that

force = mass × acceleration

$F = ma$

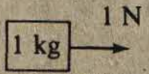
F ↗ newtons; m ↖ kilograms; a ↖ metres/second/second

The kilogram force (kgf). In *Concepts of Science 2* we used the kilogram force as a unit of force. This is the force of gravity on a mass of 1 kg. The acceleration due to gravity is approximately 9.8 m/s^2 vertically downwards. Diagrammatically,



acceleration = 9.8 m/sec^2

Remember —



acceleration = 1 m/sec^2

Thus,
1 kilogram force = 9.8 newtons

But the force of gravity is not constant over the surface of the earth. It is slightly greater at the poles than at the equator. The reason for this is that the earth is not spherical; it is slightly flattened at the poles. In fact, it is shaped somewhat like an apple. Therefore an object at the poles is closer to the centre of the earth; being closer it is pulled with a stronger gravitational force. (See figure 16.5.)

There is another factor tending to lower gravity at the equator. Because the earth is rotating, objects at the equator experience a small force tending to fling them off the earth's surface. This rotational effect does not exist at the poles.

Because gravity is slightly stronger at the poles than at the equator, the acceleration of a falling object is also greater at the poles.

g at the poles = 9.83 m/s^2
g " Sydney = 9.80 "
g " " equator = 9.78 "

where g = acceleration due to gravity

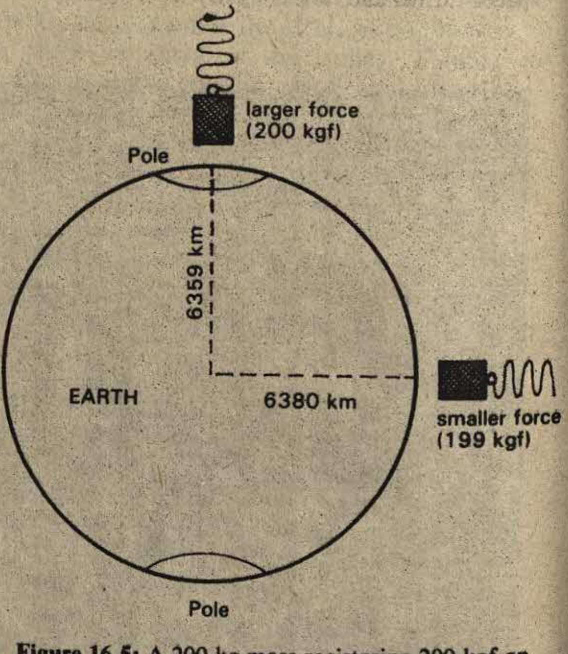


Figure 16.5: A 200 kg mass registering 200 kgf on a spring balance at the pole would register 199 kgf at the equator. This is because an object is further from the centre of the earth at the equator than at the poles. Also, there is a slight tendency for objects to be flung off at the equator because of the earth's rotation.

This leads us to the conclusion that the kilogram force is not constant. It varies by about 0.5 per cent over the earth's surface. For this reason engineers and scientists prefer the newton as a unit of force. Because the newton never varies we say it is an absolute unit of force.

Suppose we were asked how big a kilogram force is on the moon. We could answer by saying that, on the moon, 1 kgf is one fifth of what it is on earth or, more precisely, 1 kgf = 1.96 N.

Gravity meters

We have just explained how gravity varies very slightly over the earth's surface. An ordinary spring balance might show the difference between gravity at the poles and at the equator, but you would need an extremely sensitive balance to show the difference between the gravity at Sydney and at Newcastle. However, such balances can be made. They are called gravity meters. They use a spring made from a fine quartz fibre.

Gravity meters are used by geologists exploring the earth's crust in search of oil or bodies of ore. Iron ore, for example, is much heavier than ordinary rock. A large deposit of it will give a higher than usual reading on a gravity meter placed vertically above it. (See figure 16.6.)

A gravity meter does not identify particular minerals. However, it does supply information about the density of the rocks beneath the surface.

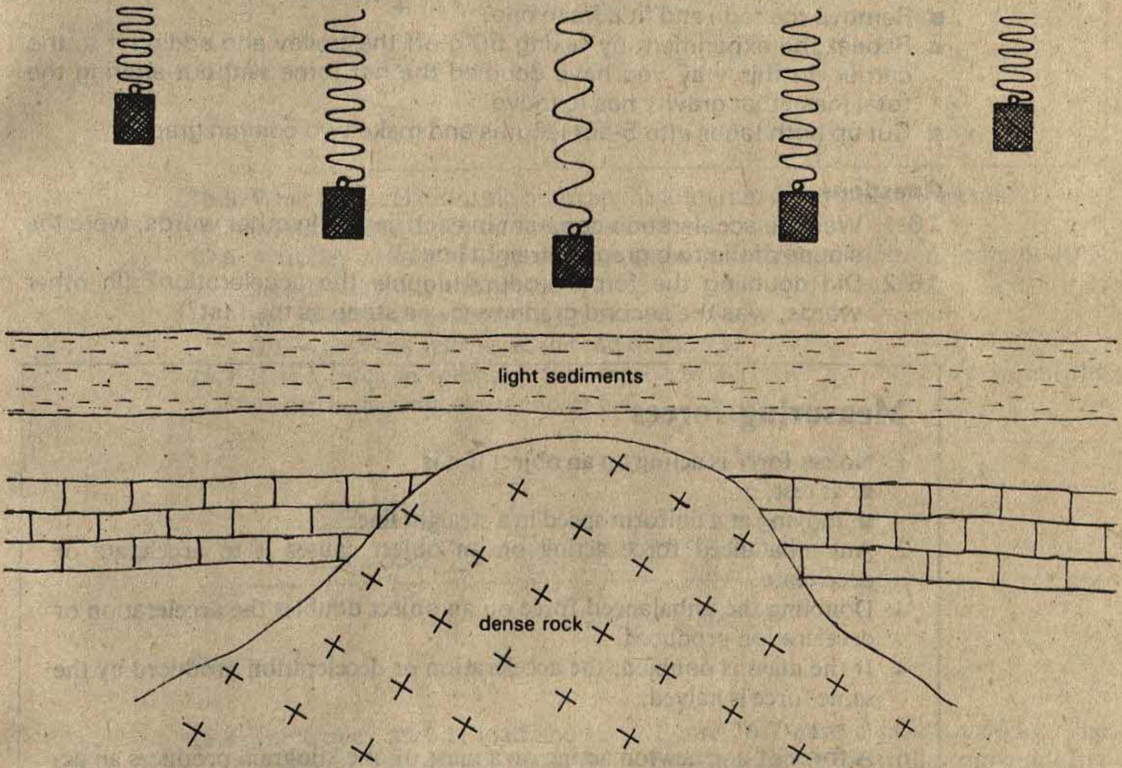


Figure 16.6: Using a gravity meter to detect the presence of a large mass of dense rock beneath the earth's surface. The value of g might change only from 9.8001 to 9.8002, but the meter would be sensitive enough to register it.

EXPERIMENT 16.1

Showing that twice the force produces twice the acceleration

Each group will need:

- trolley
- ticker-timer
- G-clamp
- battery
- paper tape
- mass carrier
- various slotted masses
- pulley
- clamp and stand
- string
- drawing pins

What to do

- Clamp the ticker-timer to the bench with the G-clamp.
- Place the trolley on the bench. Attach a length of tape to one end and a length of string to the other.
- Thread the tape into the ticker-timer.
- Pass the string over a pulley standing near the edge of the bench. Tie the mass carrier to the free end.
- Place a number of slotted masses on the trolley.
- Set the timer going and add enough masses to the carrier to cause the trolley to move steadily once given a slight push.
- Fit a fresh tape into the timer, hold the trolley and add 50 g to the carrier.
- Set the timer going and then release the trolley. This allows it to be pulled forward by the weight of the extra 50 g on the carrier.
- Remove the tape and fit a fresh one.
- Repeat the experiment by taking 50 g off the trolley and adding it to the carrier. In this way you have doubled the net force without altering the total mass that gravity has to move.
- Cut up both tapes into 5-dot lengths and make two column graphs.

Questions

16.1 Was the acceleration constant in each case? (In other words, were the slopes of the two graphs straight lines?)

16.2 Did doubling the force produce double the acceleration? (In other words, was the second graph twice as steep as the first?)

Measuring forces

1. No net force is acting on an object if it is
   - at rest, or
   - moving at a uniform speed in a straight line.
2. An unbalanced force acting on an object causes it to accelerate or decelerate.
3. Doubling the unbalanced force on an object doubles the acceleration or deceleration produced.
4. If the mass is doubled, the acceleration or deceleration produced by the same force is halved.
5. $F = ma$
6. A force of one newton acting on a mass of one kilogram produces an acceleration of one metre/second/second.
7. One kilogram force on the earth = approximately 9.8 newtons.

Spelling list

acceleration
inertia
inversely
meter (as in "gravity meter")
newton
proportional
trolley

More questions

(See appendix 2 for answers.)

16.3 Define the newton as a unit of force.

16.4 Complete the following table:

Force (N)	Mass (kg)	Acceleration (m/s^2)
4	2	?
?	4	2
10	50	?
20	5	?
50	?	2
?	2	0.5

16.5 What is the relationship between the kilogram force and the newton (a) on the earth, (b) on the moon?

16.6 A trolley of mass 5 kg rests on a smooth horizontal table. A force of 10 N acts on the trolley horizontally for 5 s.
(a) How far does the trolley move in the 5 s?
(b) What is its velocity at the end of the 5 s?

16.7 If the force in question 16.6 ceased to act after 5 s, how fast would the trolley be moving at the end of 6 s?

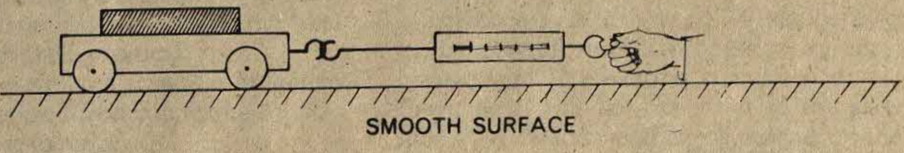


Figure 16.7

16.8 The trolley and its load shown in figure 16.7 have a mass of 50 kg. The reading on the spring balance is 5 kg. How fast is the trolley moving after being pulled in this way for 3 s?

16.9 A car of mass 3000 kg is travelling at 36 km/h. What force is needed to stop it in 5 s?

Test yourself (chapter 16)

Write the answers in your workbook.

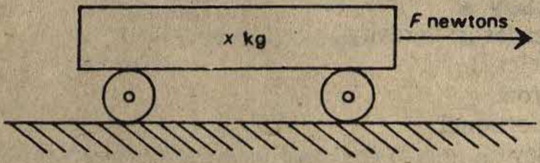


Figure 16.8

1. In the situation shown in figure 16.8, the forces of friction are so small as to be negligible. The trolley is moving with an acceleration of 4 m/s^2. What would be the acceleration if
   (a) the force was increased to $3F$ newtons?
   (b) the force remained at F newtons but the mass was increased to $3x$ kg?
2. A workman pushes a trolley of mass 100 kg across a level floor. He exerts a force of 450 newtons. Frictional forces opposing the movement of the trolley amount to 250 newtons.
   (a) What is the net force acting on the trolley?
   (b) What is the acceleration of the trolley?
   (c) With what speed will the trolley be moving 4 seconds after starting from rest?
   (d) What will be the average speed of the trolley during the 4 seconds?
   (e) How far will the trolley travel from rest in the 4 seconds.

17

Rockets and satellites

The year 1969 saw the first landing of men on the moon. A tremendous amount of scientific knowledge was used in planning this project and in designing the rockets, the spacecraft and all the other equipment needed for it. A lot of the planning depended on an understanding of the forces involved. Some of these forces are discussed in this chapter.

What drives a rocket?

In the previous chapter we briefly discussed action and reaction forces. Let us now investigate this topic more fully.

Figure 17.1 shows what happens when two kitchen scales are pushed together horizontally. The reading on each is the same. The scales must therefore be pushing on each other with equal but opposite forces.

Look at figure 17.2. In both cases we have two forces pulling against one another. The reading on the spring balance is 1 kgf in both A and B. The net force on each balance is zero; 1 kgf to the right balances 1 kgf to the left. It makes no difference whether the balance is horizontal or vertical.

Let us now examine a situation in which action and reaction forces are acting on objects that are free to move.

In figure 17.3 we have two rubber stoppers of equal size, each fitted with a glass tube and suspended centrally on a tight wire. A spring is compressed between the stoppers by tying them together with a piece of thread. The thread is then burned to release the spring. When this happens, the stoppers are pushed in opposite directions by equal forces, each reaching the end of the track in the same time.

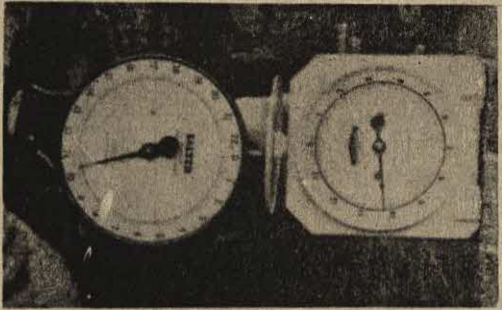


Figure 17.1: Pushing two spring balances one against the other horizontally. Each shows the same reading. The balances are therefore exerting equal forces.

The experiment is repeated using stoppers of different sizes. In these cases it is found that the lighter stopper reaches the end of its track first.

The apparatus in figure 17.4 may be used to demonstrate rocket propulsion by compressed air. The balloon is inflated and a finger held over the open end of the glass tube. The balloon is then suspended on the track and the air released. The air escapes to the left and pushes the balloon along the wire to the right.

The Saturn rocket that was used to send the Apollo mission to the moon was made to move in the same way as the balloon in figure 17.4. At the blast-off, kerosene and oxygen were burnt at the rate of 15 tonnes per second. Carbon dioxide and steam were formed and a tremendous amount of heat was given off. The heat caused these gases to expand and to be pushed out of the rocket at very high speeds. This ejection of a large amount of gas at great speed pushed the rocket upwards. The push was approximately 30 000 000 newtons. (See figure 17.5.)

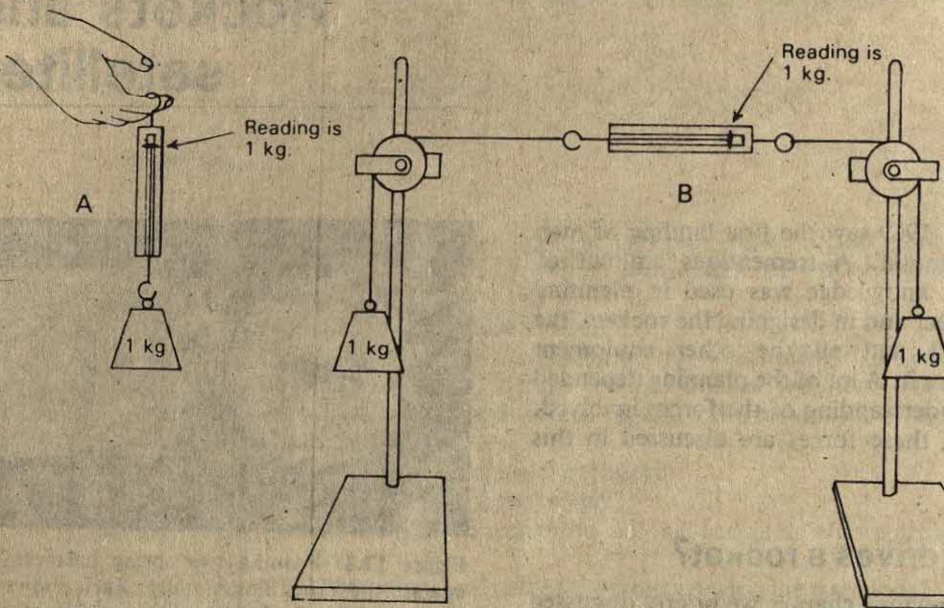


Figure 17.2: Two cases of equal and opposite forces pulling against each other. The readings on spring balances A and B are each 1 kg.

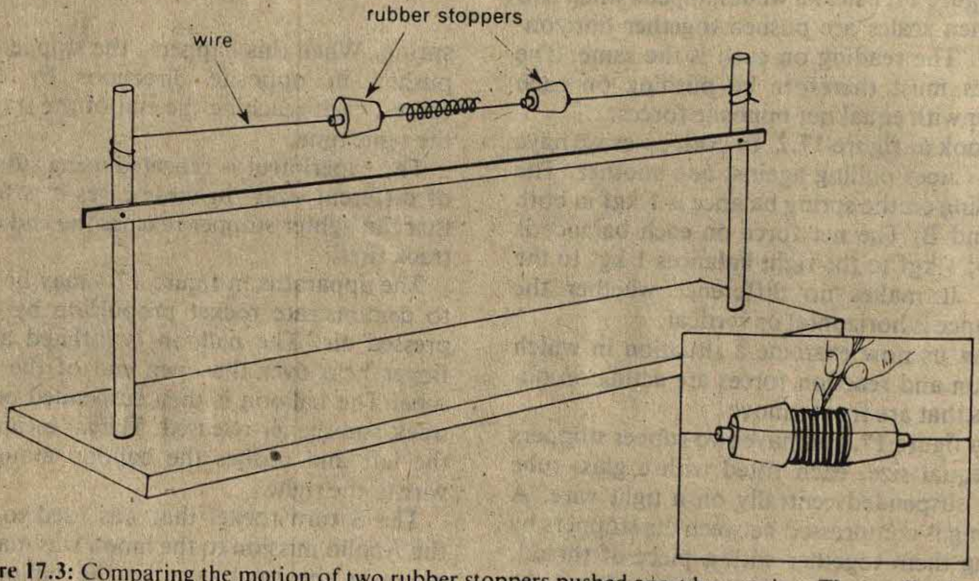


Figure 17.3: Comparing the motion of two rubber stoppers pushed apart by a spring. The smaller the stopper the faster it is pushed to the end of the track. The energy for the motion comes from the compressed spring.

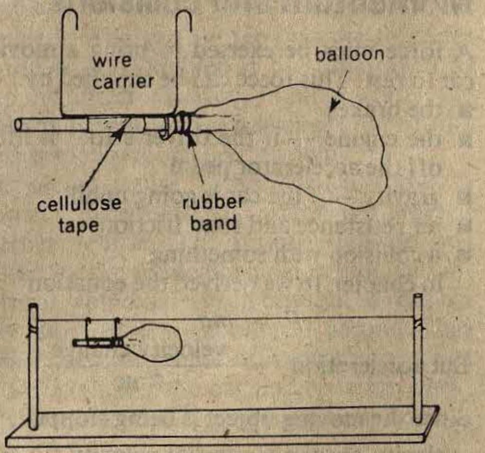


Figure 17.4: Rocket propulsion by compressed air. The balloon is pushed to the right by air moving to the left. Because the air is under pressure it contains potential energy. It is the release of this energy that causes the movement.

Action and reaction

For every force exerted there must be two objects — one to do the pushing and the other to be pushed. For example, in figure 17.1 there were two balances, one pushing against the other. In figure 17.3 we had two stoppers. In figure 17.4 it was the air pushing the balloon; in the Saturn rocket it was the exhaust gases pushing the rocket.

But not only must there be two objects, there must also be two forces. In figure 17.1 one balance pushes to the left with one force and the other pushes to the right with the second force. These two forces are equal — action and reaction are always equal and opposite. A rocket pushes the exhaust gases down; the exhaust gases push the rocket up. The two pushes, one up and the other down, are equal.

Momentum

The effect of using stoppers of different mass in the experiment shown in figure 17.3 can be studied with a movie camera. When the film is shown in slow motion it can be seen in detail (and measured) how much

Figure 17.5: The Saturn moon rocket shown immediately after take-off from its launching pad. The cloud that partly obscures the launching pad is a mixture of burnt gases. The launching pad supports the rocket until the upward thrust provided by the expanding gases is sufficient to overcome the downward force of the rocket's weight. (Photo courtesy NASA)

faster the lighter stopper moves. If the mass of the stopper is half that of the heavier stopper, it reaches the end of the wire twice as quickly. If the mass is one third that of the other stopper, its velocity is three times as great. (See figure 17.6.)

The product of the mass and velocity of a moving object is called its momentum.

$$\text{momentum} = \text{mass} \times \text{velocity}$$
$$M = mv$$

The example shown in figure 17.6 illustrates the Law of Conservation of Momentum. Before the stoppers move, the total momentum of the system is zero. After separation the total momentum is still zero — the momentum to the right cancels the momentum to the left. (The velocity in one direction is positive and in the other direction negative.)

Figure 17.7 illustrates another example of the same law. The two trolleys have equal masses. Before impact only one trolley is moving. After impact the two are joined together. Because the mass is doubled, the speed (velocity) is halved.

Momentum and collisions

A force must be exerted to bring a moving car to rest. This force can be supplied by

- the brakes
- the engine — if the driver's foot is lifted off the accelerator pedal
- gravity — if the car is going uphill
- air resistance and road friction
- a collision with something.

In chapter 16 we derived the equation

$$F = ma$$

But acceleration $= \dfrac{\text{velocity change}}{\text{time}}$

Since the moving object is being stopped,

$$\text{velocity change} = \text{initial velocity } (v) - 0$$
$$= v$$

That is, $a = \dfrac{v}{t}$

$$F = \frac{mv}{t}$$

Or, $F = \dfrac{M}{t}$

From this equation we can see that the force required to stop a moving object is

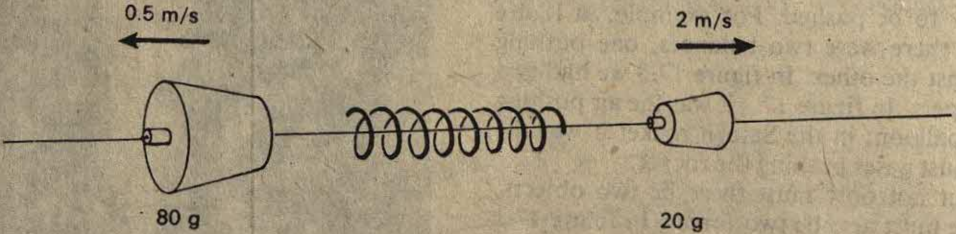


Figure 17.6: The stoppers are pushed apart by equal forces. The momentum of the small stopper is 40 units to the right. This is equal to the momentum of the large stopper to the left.

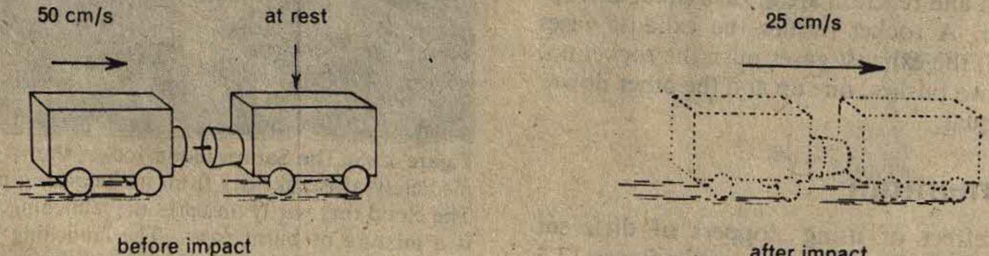


Figure 17.7: Conservation of momentum. The two trolleys have the same mass. After impact and joining together, they move off with only half the speed of the single trolley before impact.

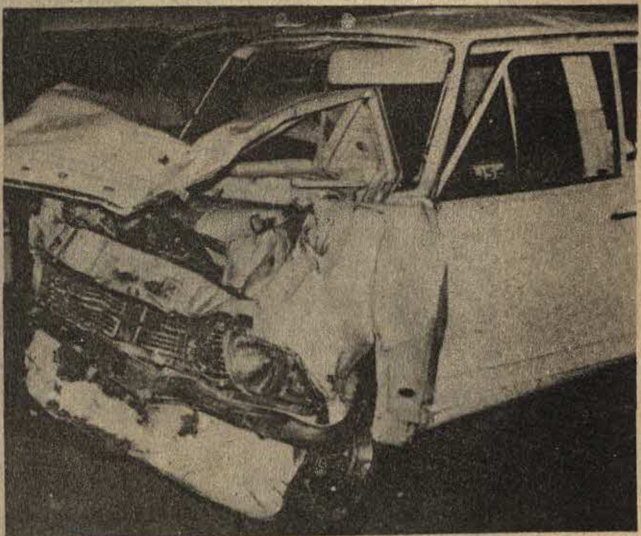
doubled if the object's momentum is doubled. We can also see that the force required is also doubled if the time taken to stop the object is halved. In other words, the more quickly an object is brought to rest, the greater the force required to do it.

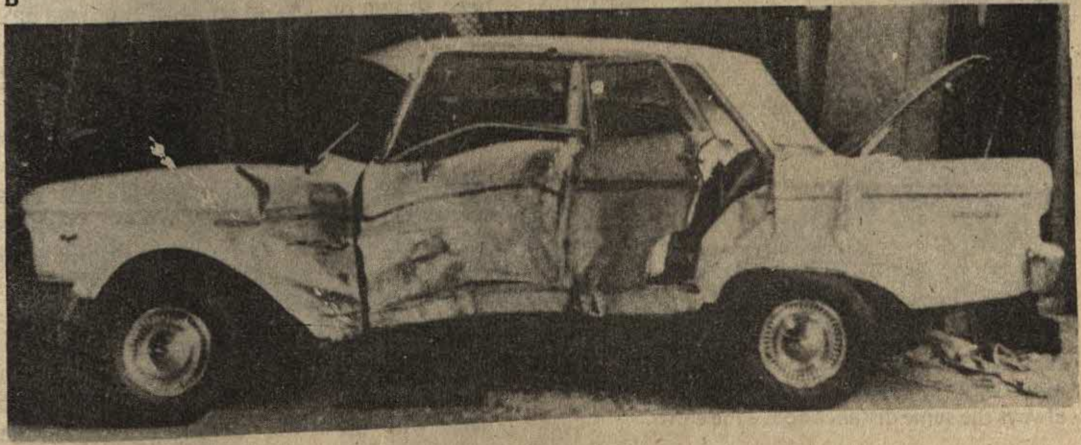
Look at figure 17.8A, which shows a motor vehicle that has struck the side of another vehicle. The serious damage was caused by the sudden change in momentum. This car would have been brought to rest in a very short time — about 0.1 second. This would make the force of impact very great. If, for example, the car had hit a haystack, very little damage would have been done; it would have stopped in about one second. This would have reduced the force of impact to one tenth.

As figure 17.8A indicates, car manufacturers tend to make cars that will crumple in a collision like a concertina. If this car had not crumpled, the force of impact would have been much greater, and the passengers would have been killed.

There is also an increasing use of rubber in bumper bars. In fact, some cars now have so much rubber on their bumper bars that they can survive a collision of about 10 km/h without any damage to the vehicle whatsoever.

Figure 17.8A and B: The result of a collision between two cars, car A hitting the side of car B. Both cars were travelling at about 60 km/h. Car A is a 1970 Ford Cortina. Its front crumpled 43 cm. Seat belts saved the four occupants from serious injury. Car B is a Ford Falcon. Its side was pushed in 65 cm. In spite of wearing seat belts, both occupants were killed. (Photos courtesy Traffic Accident Research Unit of N.S.W.)





Satellites

The experiment illustrated in figure 17.9 shows that the two coins fall to the floor in the same time. One coin drops vertically, the other is projected horizontally.

This experiment helps us to understand how a satellite is placed in orbit around the earth. (See figure 17.10.)

The satellite is first pushed to the required height by a rocket. The rocket is then turned so that it travels parallel to the earth's surface. The turning is brought about by the rocket's firing slightly sideways instead of downwards. Once the rocket is travelling horizontally, firing continues until a speed of 28 000 km/h is reached. This is the speed at which a satellite must travel to orbit the earth at an altitude of 160 km. When this speed is reached, the rocket stops firing and automatically separates from the satellite. The satellite then begins to fall towards the earth in a curved path like that of the coin in figure 17.9. However, it is moving so fast that it does not reach the earth but travels in a curved path that is always the same distance above the earth's surface.

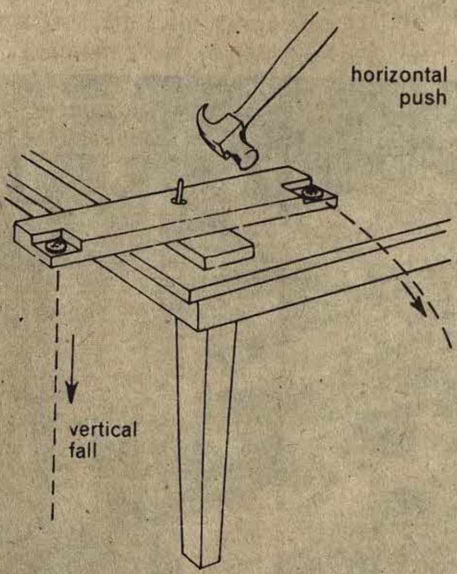


Figure 17.9: Showing that the times of fall of both objects are equal — the two coins hit the floor at the same time.

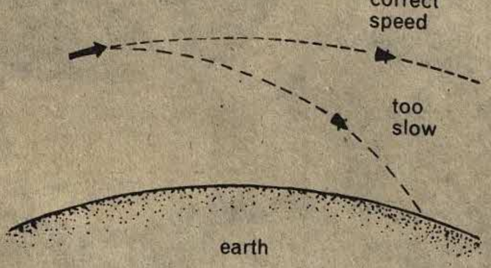


Figure 17.10: A satellite in a circular orbit must move with the correct speed so that as it falls it is always the same distance above the earth.

In order to remain in orbit forever, the satellite must continue to travel at 28 000 km/h. This does not happen because, at an altitude of 160 km, there is a trace of atmosphere. In pushing through this atmosphere the satellite slowly loses energy and eventually falls to the earth like a meteor.

At a higher orbit a satellite needs less speed. For example, the moon, which is 384 000 km from the earth, travels at only 3520 km/h to maintain its orbit around the earth.

There is no possibility of the moon's losing energy and falling on to the earth because the earth's atmosphere does not extend as far as the moon's orbit.

Weightlessness

Many films of Apollo moon missions have been shown on TV. In some of them we have seen men floating about inside their spaceship. Apparently these men are weightless. What is the cause of this?

Hold a kilogram mass in your hand and jump from a chair to the floor. While you are falling you will notice that the iron mass appears weightless. This happens because both you and the iron mass are falling at the same rate.

We have just explained that a satellite remains in orbit because it falls freely in a curved path. Consequently objects inside the satellite also fall freely, in the same path. They will fall at the same rate whether they are inside or outside the satellite. When inside they therefore "float" and appear weightless.

Figure 17.11 is a sketch of the Apollo 15 spaceship returning from the moon. The spaceship's motors are shut down. It is therefore falling towards the earth. The men inside fall at the same rate. This rate could be many kilometres per hour.

If a man climbs out of the spaceship he still falls at the same rate. Therefore very little effort is required for him to remain attached to the spaceship. Remember also that the spaceship is moving through a vacuum; there is no air resistance operating against either the spaceship or the man.

Moon missions

A Saturn rocket was used for the Apollo 15 moon mission. This rocket weighed 3000 tonnes and was 111 metres high — higher than a 35-storey building. It was made up of three stages, with the spacecraft on top of the third stage. The first stage used kerosene and liquid oxygen as fuel and the second stage used liquid hydrogen and liquid oxygen. These two stages placed the third stage, with the spacecraft attached, in orbit around the earth.

The fuel for the third stage was also liquid hydrogen and liquid oxygen. This stage was used to give the spacecraft the extra speed needed to push it away from the earth's gravity and send it to the moon. This speed, called the escape speed, is 40 000 km/h. Once the escape speed is reached, the rocket motors are shut off and the spacecraft coasts through space.

The spacecraft itself weighed more than 45

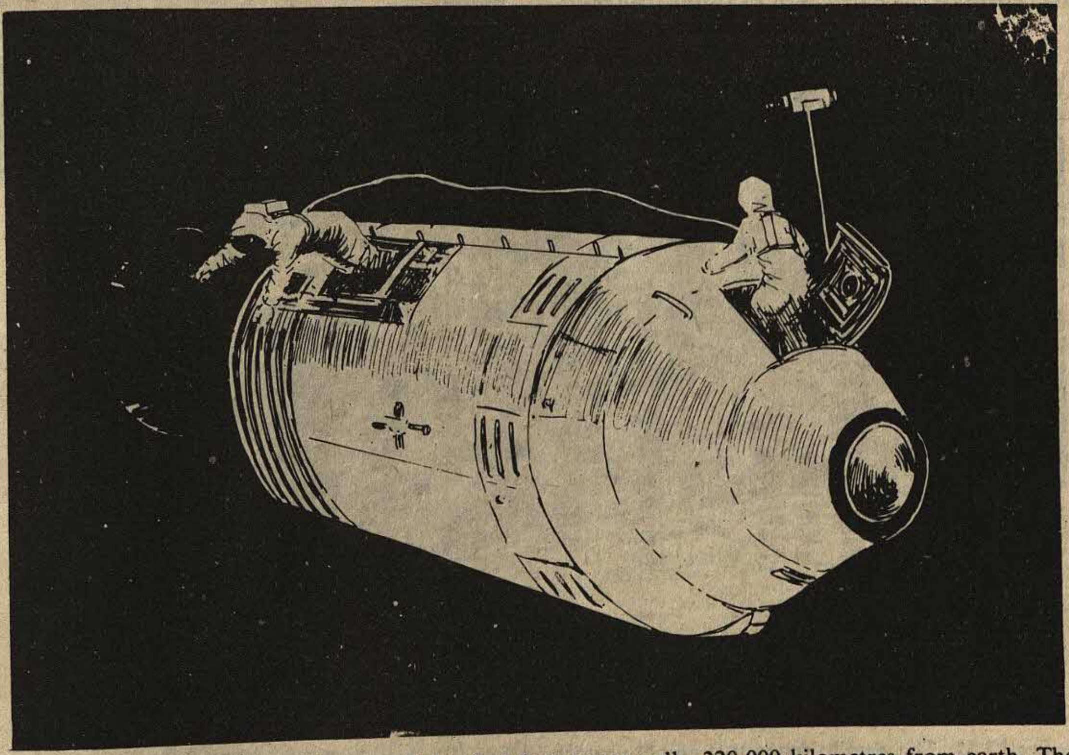


Figure 17.11: An artist's impression of the first deep space walk, 320 000 kilometres from earth. The rocket motors are shut off and the men and the spaceship are falling freely in a vacuum.

tonnes. It was made up of three sections. These are shown in figure 17.12. They are:

- The command module, which carried the astronauts and contained most of the instruments. It was cone-shaped and was the only part that returned to earth.
- The service module, which contained the main rocket motor, its fuel and some instruments.
- The lunar excursion module, called the Falcon, which carried the astronauts from the command module to the moon's surface and back again.

As a spacecraft coasts towards the moon its speed gradually drops. This happens because it is being pulled backwards by the earth's gravity. This pull decreases rapidly with distance from the earth. The rate at which it decreases is shown in table 17.1.

Table 17.1 shows that, for a body moving away from the earth, the pull of gravity decreases as the square of the distance from the centre of the earth. For example, the pull of gravity 32 000 km from the centre of the earth is only $\frac{1}{25}$ of what it is on the earth's surface. (A height of 32 000 km is five times as far from the centre of the earth as the earth's surface, and $5^2 = 25$.)

Table 17.1: Decrease of earth's pull with distance

Distance from centre of earth	Pull by the earth
6 400 km (earth's surface)	1
12 800 km (6400 × 2)	$\frac{1}{4}$
19 200 km (6400 × 3)	$\frac{1}{9}$

As the spacecraft moves on, it eventually comes to a point where the pull of the earth's gravity backwards just balances the pull of the moon's gravity forwards. It is as though the spacecraft had come to the top of a long hill. This point is 345 600 kilometres from the earth and 38 400 kilometres from the moon.

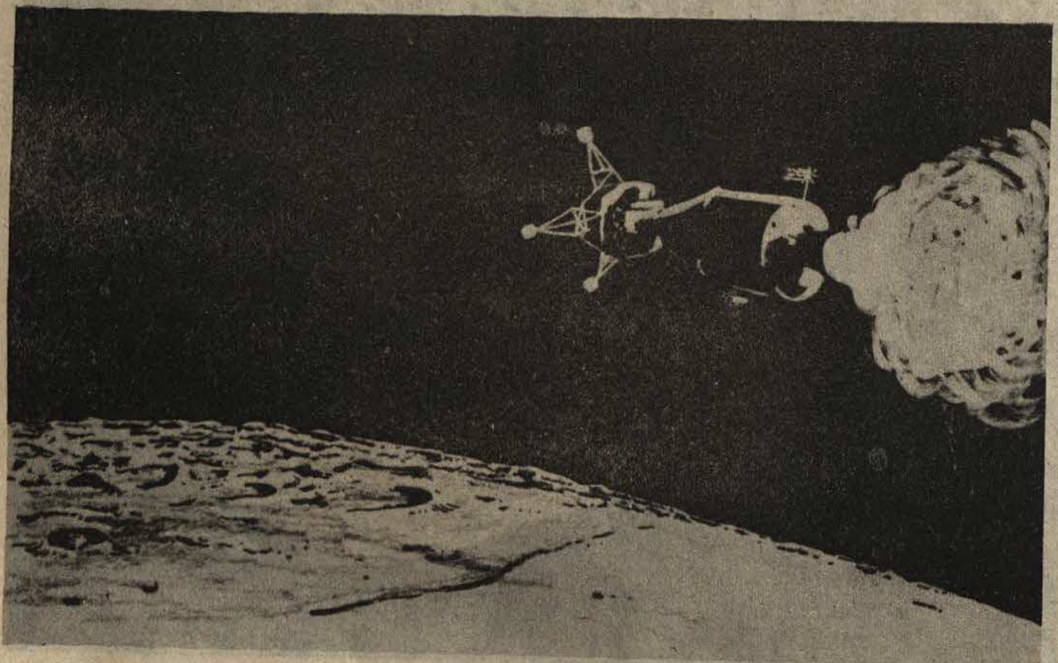


Figure 17.12: The Apollo spacecraft going into orbit around the moon. It is moving to the right and the rocket in the service module is firing to reduce the speed to 6400 km/h. The crew is in the cone-shaped section between the "Falcon" and the service module.

Once past this point, the spacecraft gathers speed because it is now falling towards the moon. During this fall its direction is controlled by small side rockets so that it will just miss the moon and swing around behind it. Its speed must now be reduced to 6400 km/h. At this speed the spacecraft will go into lunar orbit 160 km above the moon's surface. (See figure 17.12.) At a higher speed it would move further away from the moon.

Once the Apollo 15 spacecraft was in orbit, the actual descent to the moon's surface was made in the Falcon. This contained a much smaller rocket motor than the service module and carried only enough fuel for the descent and return to the command module. (To put the whole spacecraft down on the moon and to lift it off again would have required much more fuel than the spacecraft was carrying.)

The return journey to earth was made without the Falcon; it was detached after the astronauts had climbed from it back into the command module. The service module, in its turn, was jettisoned just before reaching the earth's atmosphere.

Very careful control is needed to bring the command module down on to the earth's surface. The angle of entry must be between six and seven degrees. If the entry is any steeper, the retardation will be too rapid and the command module will burn up like a meteor. If it is any flatter, the command module will bounce off the earth's atmosphere and be lost in space. Even at the correct angle, part of the skin of the module melts in the tremendous heat that is generated. The final slowing down is achieved with parachutes.

EXPERIMENT 17.1

How fast do two trolleys recoil from each other?

Each group will need:

- two trolleys (preferably spring-loaded)
- several kilogram masses
- spring balance to weigh trolleys
- metre ruler
- chalk

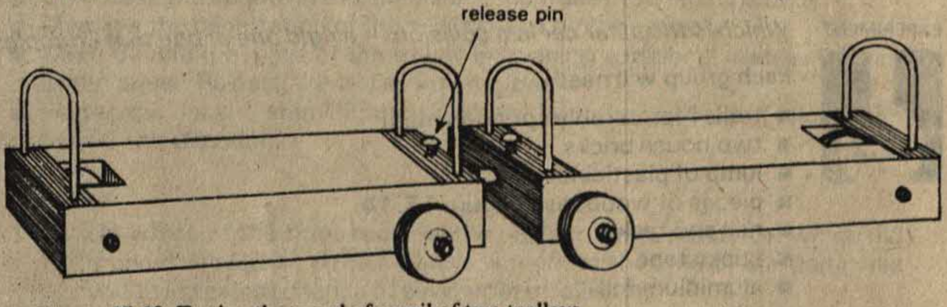


Figure 17.13: Testing the speed of recoil of two trolleys.

What to do

- Weigh the two trolleys. If they are not equal, add sufficient masses to the lighter one to make them equal.
- Choose a smooth, level surface such as the floor or the top of a bench. On the surface draw two chalk marks about 3 metres apart, and a line to join them, making a track.

- Compress the springs in the trolleys and set the release pins. (Alternatively, a spring clothes peg tied together with cotton may be used.)
- Place the two trolleys back to back in the middle of the track marked out on the bench or floor.
- Press one of the release pins or burn the cotton holding the clothes peg together.

Question

17.1 Did you find that the two trolleys reached their respective ends of the track in the same time?

- Add masses to one of the trolleys until its total mass is doubled.
- Try to estimate the position in which to place the trolleys so that, when released, they will reach the ends of the track at the same time. Try different positions until you get the correct one. Then measure the distance each trolley travels.
- Repeat, making one trolley three times as heavy as the other.
- Record your results as follows:

Mass of trolley A	Distance it moves in same time	Mass of trolley B	Distance it moves in same time

Question

17.2 From your results, write a conclusion about the masses of the trolleys and the distances they move when pushed apart by a spring.

EXPERIMENT 17.2

Which is the safer car in a collision — a rigid one or one that crumples?

Each group will need:

- trolley (preferably spring-loaded)
- two house bricks
- lump of plasticine
- pieces of wood, as in figure 17.14
- nail and tacks
- sticky tape
- aluminium foil
- kilogram masses

What to do

- Set up the apparatus (without the aluminium foil) as shown in figure 17.14. A nail is driven through one of the pieces of wood. This piece of wood is held in place by being tacked to the second horizontal piece.
- The lump of plasticine is the "driver". The third piece of wood supports the "driver" while the trolley is accelerating.

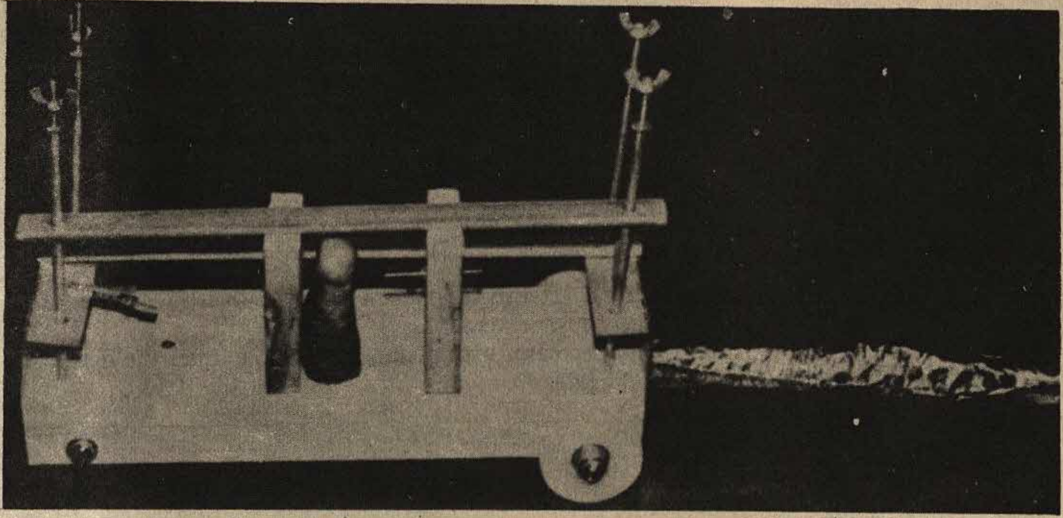


Figure 17.14: A trolley designed to test the effects of car collisions on passengers. The lump of plasticine is the "driver". The distance the nail penetrates measures the force of impact. The aluminium foil tube is used to produce a crumpling effect.

- Place the house bricks on the bench, about a metre apart.
- Compress the spring in the trolley so that it is held by the release pin.
- Back the trolley up against one house brick. Release the spring so that the trolley is propelled towards the second house brick. (A spring clothes peg may be used if a spring-loaded trolley is unavailable.)
- Measure the distance the nail penetrates the "driver".
- Cut two equal strips of aluminium foil. Roll each into the form of a cylinder. It is important that the two cylinders be identical.
- Fasten one cylinder to the trolley with sticky tape. (See figure 17.14.)
- Compress the spring and again release the trolley towards the brick.
- Measure the penetration of the nail, caused by the impact.
- Next, double the mass of the trolley by placing additional masses in front of the driver. Release the trolley into the brick.
- Fasten the second aluminium cylinder to the trolley and again release the trolley into the brick.

Question

17.3 On which of the three runs did the nail penetrate most? On which did it penetrate least? Write a conclusion about the kind of car that gives you the greatest chance of survival in a collision.

Spelling list

balloon
collision
jettison
lunar
meteor
meteorite
module
momentum
orbit
plasticine
satellite
trolley

Rockets and satellites

- When one object acts on a second object, the second object reacts on the first.
- Action and reaction are equal and opposite.
- Momentum = mass × velocity.
- In the case of two objects separating or colliding, the total momentum of the objects remains the same.
- Satellites in orbit are constantly falling in a curved path around the earth.
- Objects falling freely appear weightless.
- The pull of gravity decreases with distance. At three times the distance there is one ninth the pull.

Things to do

17.4 Experiment with skateboards and a length of cord. Ask two people to stand on skateboards facing each other and to hold a length of cord between them. What happens when

(a) one person pulls on the cord?
(b) both persons pull on the cord?
(c) two persons on one board pull one person on another board?

17.5 Look at figure 17.15. Guess the reading on the spring balance when the heavier mass is supported as shown. What would be the reading if the heavier mass were allowed to fall freely? Set up the apparatus and check your answers.

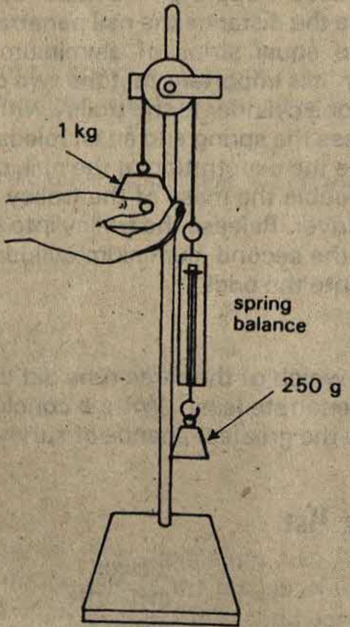


Figure 17.15: What is the reading on the spring balance when the 1 kg mass is supported in the hand? What is the reading if the heavier mass is allowed to fall?

More questions

17.6 Which has the greater momentum — a 1 t car travelling at 110 km/h or a 5 t truck travelling at 20 km/h?

17.7 A gun weighing 4 kg fires a bullet at 480 m/s. If the bullet weighs 10 g, what is the velocity of recoil of the gun?

17.8 Why should a rifle be held firmly against the shoulder when it is fired?

17.9 Draw diagrams illustrating the following situations and mark the action and reaction forces on each.
- (a) a person standing on a floor
- (b) a golf club hitting a golf ball
- (c) an engine pulling a train.

17.10 Explain why a Saturn V rocket carries both fuel and oxygen and a jet aircraft carries only fuel.

17.11 Explain how a satellite is placed in orbit around the earth. Why does such a satellite fall back to the earth if its speed decreases?

17.12 Why is gravity less on the moon than on the earth?

17.13 Why was the Apollo 11 spacecraft able to coast for most of its journey from the earth to the moon?

17.14 What is the weight of a 100 t spacecraft 32 000 km from the earth's surface?

17.15 The weight of an object 100 km above the earth's surface is very little less than it is on the surface itself. Why?

17.16 Why is the neutral point between the earth's gravity and the moon's gravity much closer to the moon?

Test yourself (chapter 17)

Write the answers in your workbook.

1. A boy pushes on two boxes in turn, using the same force on each. One box accelerates more rapidly than the other. In what fundamental property do they differ?
2. Two cars of equal mass, both travelling at 8 km/h, are involved in separate accidents. Car A strikes an object that brings it to rest in 0.5 s. Car B strikes an object that brings it to rest in 0.1 s. In which case is the force of impact greater?
3. The earth's radius is 6400 km. How far above the earth's surface is the force of gravity one quarter of what it is on the surface?

Choose the best answer to each of questions 4 to 7 and write its letter in your workbook.

4. A big boy and a small boy are both standing still on ice. Both are wearing skates. The small boy gives the big boy a hard push from behind. As a result,
   - (a) the small boy travels backwards but the big boy remains where he is
   - (b) the big boy travels forwards but the small boy remains where he is
   - (c) both boys move but the small boy moves faster than the big boy
   - (d) both boys move, but the big boy moves faster than the small boy.

5. A sensation of weightlessness will be experienced by a person inside a compartment that is
   (a) being accelerated in space by rocket motors
   (b) being decelerated in space by rocket motors
   (c) falling freely
   (d) well above the earth's surface.
6. When a spaceship returning from the moon enters the earth's atmosphere at high speed, the outside of the spaceship becomes hot. This heat energy is produced mainly from
   (a) light energy
   (b) mechanical energy
   (c) chemical energy
   (d) electrical energy.
7. Of the following pieces of information, which one would be of least value to a space scientist planning a trip to the moon?
   (a) The moon orbits around the earth.
   (b) The earth is spinning.
   (c) The earth is the third planet from the sun.
   (d) The moon has a gravitational attraction.
   (e) The moon's distance from the earth is not constant.

18

Work, energy, power

Work

Usually we think of work as something that requires either mental or physical effort. However, to the scientist and the engineer, work is done only when an effort moves something. A man struggling to lift a heavy box off the ground does no work where the box is concerned until he actually moves it. He certainly uses up energy in trying to move it but this becomes apparent in other ways, such as the production of heat, which results in sweating. But he does no work on the box until he moves it.

Most of our work is done in the following ways

- in lifting things (overcoming gravity)
- in getting things to move (overcoming inertia)
- in stopping things (overcoming inertia)
- in moving things over rough surfaces (overcoming friction).

Figure 18.1: The bulldozer is working to overcome the friction or drag between the rocks and the ground. It is also working against the inertia of the rocks. (Photo courtesy Tutt Bryant — N.S.W. — Pty Ltd)

Measurement of work

The bulldozer shown in figure 18.1 is working hard. It is exerting a large force to push the rocks and earth along — it is overcoming friction and inertia. The bigger the heap it moves, the more work it does. As well, the further it pushes the heap, the more work it does.

Work = force × distance

$$W = Fs$$

A unit of work. A unit of work is the joule. One joule of work is done when a force of one newton is exerted through one metre.

$$W = Fs$$

joules = newtons × metres

Energy

Potential or waiting energy

Potential energy is stored energy; it may be said to be waiting to be used. Water stored in a dam has potential energy. This energy can be used to drive a power station by releasing the water so that it presses against the blades of a turbine. The power station containing the turbine must, of course, be below the level of the water in the dam.

A wound-up clock spring has potential energy; so has gas under pressure.

A wound-up spring has energy because we do work in winding it. The more work done in winding up the spring, the more potential energy it holds.

To put a gas under pressure you have to use a pump. The more pumping you do, the greater the potential energy of the compressed gas.

Some clocks are driven by a falling weight attached to a chain. Figure 18.2 shows such a clock. It is energized by someone lifting the weight, that is, by work against gravity. The weight then slowly falls, releasing potential energy. It is the release of this potential energy that drives the clock. Because this energy depends on the pull of gravity it is called gravitational potential energy.

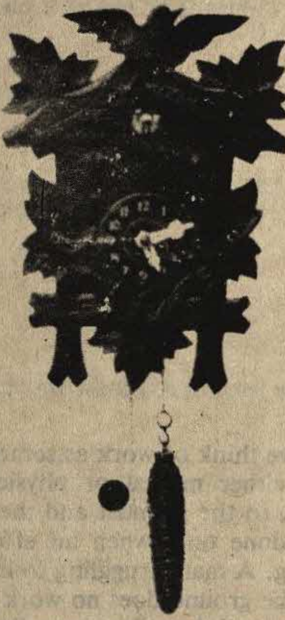


Figure 18.2: A clock worked by gravity. It is kept going by the release of potential energy. The chain exerts a force on the mechanism of the clock. The movement of this force works the clock.

Measurement of gravitational potential energy

When two suspended weights, of the same size and shape, are allowed to drop on to plasticine, it is found that the heavier weight penetrates further than the lighter weight. (See figure 18.3.) Since work is done in pushing anything into plasticine, we can say that the heavier weight had more energy.

It can also be shown that the greater the distance a weight drops, the further it penetrates.

From these two observations it is apparent that the potential energy of a suspended object depends upon two factors:

- the weight of the object
- the vertical height it falls from when released.

This conclusion is seen to be reasonable when we think of the potential energy of water in a dam. The amount of energy available for use in a power station below the dam depends upon:

- the amount of water in the dam
- the vertical drop from the dam down to the power station.

Potential energy = weight × vertical drop

The weight of an object is the force of gravity on it.

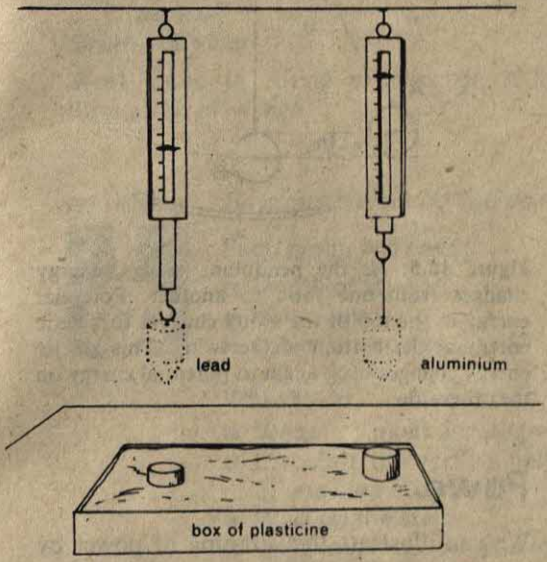


Figure 18.3: Comparing potential energies. When dropped from the same height, the lead object penetrates the plasticine further than the aluminium weight. The lead does more work; therefore, it had more energy. This is because the lead had more weight.

Force to lift 1 kg = 1 kilogram force
= 9.8 newtons
” ” ” 2 ” = 2 × 9.8 ”
” ” ” m ” = $m \times 9.8$ ”
Work done to lift m kilograms h metres vertically = force × distance
= $m \times 9.8 \times h$
Potential energy of m kilograms = $m \times 9.8 \times h$ joules
Thus, P.E. = mgh
where g = acceleration due to gravity.

Kinetic energy — energy on the run

Drivers of heavy trucks that travel long distances make good time by allowing their trucks to gather speed down one hill in order to climb the next quickly and easily. The faster a truck is travelling at the bottom of a hill, the further its motion carries it up the hill without the help of the engine. At the bottom of the hill the truck has a lot of kinetic energy. This is changed to potential energy as the truck gains height and loses speed.

Look at figure 18.4. This figure illustrates an experiment that shows that when a trolley runs down a slope from a given height, its speed at the bottom is the same whether the slope is gentle or steep. In each case the truck runs the same distance on to the flat before coming to rest. Even if the drop were vertical, the speed at the bottom would be the same.

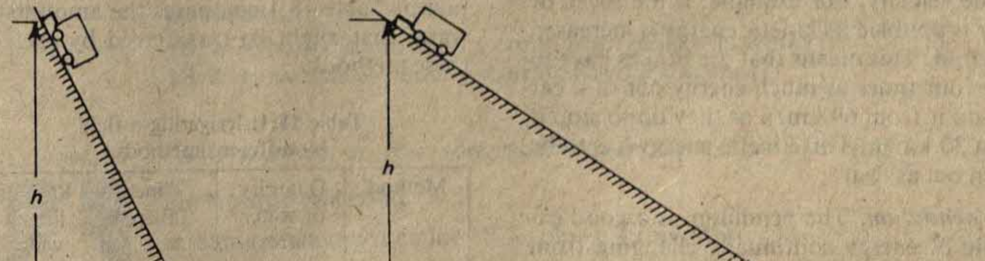


Figure 18.4: The speeds of the trucks will be equal when they run out on to the level stretch.

The potential energy of the trolley at the top of the slope is *mgh* joules. This has all been changed to kinetic energy at the bottom. Can we find a formula for this kinetic energy?

Suppose the speed at the bottom of the drop is v metres per second.

Using the equation

$$v = u + at$$

we can write

$$v = gt \qquad (u = 0, a = g) \ldots\ldots \textit{Equation 1}$$

To find a value for t, we use the equation

$$s = \frac{u + v}{2}\,t$$

This equation becomes

$$h = \frac{vt}{2} \qquad (u = 0, s = h)$$

i.e.,

$$t = \frac{2h}{v}$$

Substituting in equation 1,

$$v = g \times \frac{2h}{v}$$

$$v^2 = 2gh$$

or $\frac{v^2}{2} = gh$

Multiplying both sides by m,

$$\frac{mv^2}{2} = mgh$$

Therefore, $\frac{mv^2}{2}$ is the kinetic energy of the object at the bottom of the drop.

It will be noticed that the kinetic energy of a moving object is proportional to the square of the velocity. For example, if the speed of a car is doubled its kinetic energy is increased fourfold. This means that the brakes have to take four times as much energy out of a car to stop it from 60 km/h as they do to stop it from 30 km/h. This kinetic energy has to be taken out as heat.

The pendulum. The pendulum is a good example of energy continually changing from potential to kinetic and back again. (See figure 18.5.)

potential energy at A = kinetic energy at B

$$mgh = \tfrac{1}{2}mv^2$$

(where h is the vertical height the pendulum bob moves in its swing, and v is the bob's velocity at the lowest point of its swing)

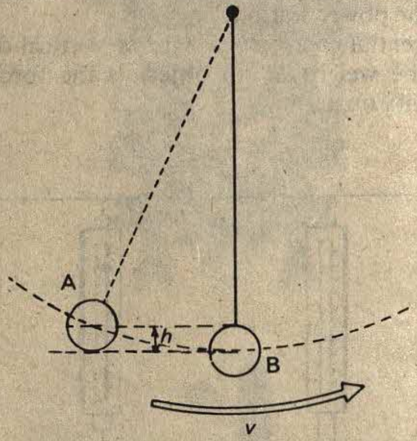


Figure 18.5: As the pendulum swings, energy changes from one form to another. Potential energy at the top of the swing changes to kinetic energy at the bottom of the swing. This kinetic energy changes back again to potential energy on the other side.

Power

We can illustrate the meaning of power by imagining a field being irrigated by three different farmers. A primitive and solitary farmer might carry water up from a river, a bucketful at a time. Another farmer might have help from his neighbours and form a human chain from the river to the field. A modern farmer would install an electric pump. Table 18.1 compares the amounts of water that might be transferred by each of these methods.

Table 18.1: Irrigating a field by different methods

Method	Quantity of water (litres)	Time taken	Rate of lifting water (litres/min)
1	50	5 min	10
2	50	30 sec	100
3	50	5 sec	600

In the third case, water is being pumped 6 times as fast as by the second method and 60 times as fast as by the first. What we are comparing is the power — the rate of doing work.

Let us calculate the power in the third case, assuming that the vertical lift from the river to the field is 10 metres.

The mass of 1 litre of water = 1 kg (approx.)

mass of 50 litres of water = 50 ” ”

Work done in lifting a mass of 50 kg through 10 m = *mgh*

$$= 50 \times 9.8 \times 10$$

$$= 4900 \text{ joules}$$

$$\text{time} = 5 \text{ seconds}$$

$$\text{power} = \frac{\text{work}}{\text{time}}$$

$$= \frac{4900}{5}$$

$$= 980 \text{ joules per second}$$

A power of one joule per second is called one watt (W).

Therefore, power = 980 W

But 1000 W = 1 kW

Therefore, the power of the farmer's pump is a little less than one kilowatt.

EXPERIMENT

18.1

How much work do you do against gravity when climbing a flight of stairs?

Each group will need:

- length of string
- metre ruler
- bathroom scales

What to do

- Weigh yourself (in kilograms).
- Calculate the vertical height of the flight of stairs by measuring the height of one step and multiplying by the number of steps.
- Walk up the stairs.
- Calculate the work you have done in the following way.

Your mass = ? kg
Force of gravity on your body = ? N
Vertical distance your body was lifted = ? metres
Work done = force × distance
= ? × ?
= ? joules

Questions

18.1 Where did the energy come from to do this work?

18.2 How was the energy carried to your muscles?

EXPERIMENT

18.2

At what power do you work when running up a flight of stairs?

Each group will need:

- same equipment as for 18.1, plus a stopwatch

What to do

- Ask your partner to time you while you run up the same flight of stairs you used in experiment 18.1.

- Calculate your power, using the formula

$$\text{power} = \frac{\text{work}}{\text{time}}$$
$$= \text{? joules per second}$$

Since 1 joule per second = 1 watt, you have calculated your power in watts.

Questions

18.3 What was your power?

18.4 Who worked with the greatest power in your group? Was it this person because he or she was the heaviest or because he or she ran up the stairs in the shortest time?

EXPERIMENT

18.3

Finding the power of an electric motor

Each group will need:

- small electric motor
- power pack or dry cells
- connecting wire
- switch
- clamp and stand
- capstan block
- pulley
- cord
- mass carrier
- various slotted masses
- metre ruler

What to do

- Set up the apparatus as shown in figure 18.6.

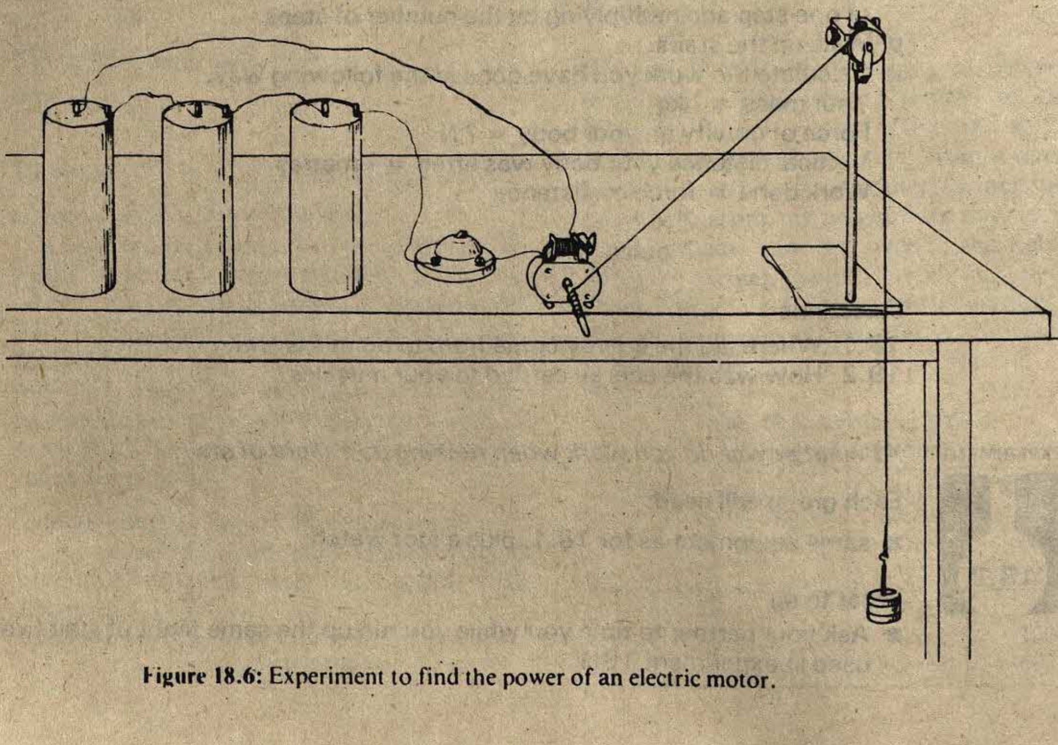


Figure 18.6: Experiment to find the power of an electric motor.

- Make test runs with the motor to find out what is a reasonable load for it to lift.
- Using the stopwatch, record the time it takes the motor to lift the load 0.5 m.
- Calculate the power of the motor, using the same method as in experiments 18.1 and 18.2.

Questions

18.5 What was the power of the motor?

18.6 Was all the electrical energy used to lift the weight? How do you know?

18.7 Would it be possible for the motor to lift four times this weight? Would this make its power greater? Discuss.

Work, energy, power

- Work = force × distance.
- One joule of work is done when a force of one newton is applied through a distance of one metre.
- Potential energy is waiting or stored energy.
- Gravitational potential energy = mgh.
- Kinetic energy is energy of movement.
- Kinetic energy = $\frac{1}{2}mv^2$.
- A unit of energy is the joule.
- Power = $\frac{\text{work}}{\text{time}}$
- A unit of power is the watt.

1 watt = 1 joule per second
1000 watts = 1 kilowatt

Spelling list

inertia	pendulum
install	plasticine
joule	potential
kinetic	watt

Things to do

18.8 Find out the power of some of the appliances in your home, such as the vacuum cleaner and the refrigerator.

18.9 What is the power of your family's car? Does a car work at the same power under all conditions? If not, when does it work at maximum power?

More questions

Assume that $g = 10\ m/s^2$. See appendix 2 for answers to calculation questions.

18.10 Why are dams that have power stations associated with them usually built in the mountains?

18.11 In what way is work done in
- (a) pushing a barrow along a level path?
- (b) bowling a cricket ball?
- (c) stretching a rubber band?
- (d) pumping up a tyre?

18.12 Which of the following have potential energy, which have kinetic energy and which have both?
- (a) a wound-up clock spring
- (b) a truck travelling along a level road
- (c) a football passing over the top of the goal posts
- (d) air compressed into a tank
- (e) a man standing still
- (f) a spinning flywheel (used to make a piston engine run smoothly).

18.13 Complete the following tables:

Table A

Force	Distance	Work
20 N	10 m	? J
5 N	? m	100 J
? N	20 m	200 J
100 N	50 cm	? J
? N	4 m	2 J

Table B

Mass	Height	Potential energy
10 kg	20 m	? J
5 kg	? m	100 J
? kg	10 m	200 J
200 kg	20 cm	? J

Table C

Mass	Velocity	Kinetic energy
10 kg	5 m/s	? J
10 kg	10 m/s	? J
20 kg	? m/s	1000 J
20 kg	? m/s	500 J
? kg	25 m/s	625 J

Table D

Work	Time taken	Power
500 J	20 s	? W
1 200 J	1 min	? W
? J	2 min	20 W
? J	1 min	2 kW
10 000 J	? min	5 kW

18.14 What work is done in picking up off the floor an apple of mass 200 g and placing it on a table? The height of the table is 1 m.

18.15 A car travelling at 15 m/s begins to free-wheel uphill. To what height will it rise, assuming there is no drag due to friction?

18.16 See figure 18.7. A car on a big dipper starts from rest at A. What is its speed at B?

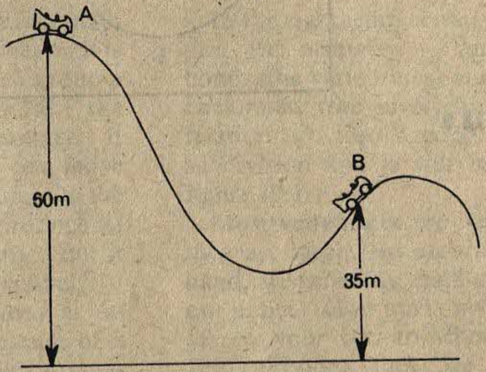


Figure 18.7

18.17 Which has the greater energy — a ball of mass 1 kg at a height of 1 m, or a ball of mass 1 kg moving at 2 m/s?

18.18 A car of mass 1000 kg travelling at 30 m/s is brought to rest. How much energy is changed into heat in the brakes?

18.19 A boy weighing 50 kg climbs to a height of 8 m. How much work is done against gravity? What is his power if he does this in 3 s?

18.20 A mini-car of mass 500 kg accelerates from rest to 15 m/s in 5 s. Find

(a) its kinetic energy

(b) the work done to give it this kinetic energy

(c) its power.

Test yourself (chapter 18)

Write the answers in your workbook.

1. Name a unit of (a) work, (b) energy, and (c) power.
2. What work is done in lifting 20 kg of potatoes 2 metres vertically on to a shelf?
3. What is the power of an engine that is pumping 25 kg of water 30 metres vertically per minute?

4. A car travelling at 20 km/h can be stopped in 20 metres by its brakes. Assuming that the brakes apply a uniform force over all speeds, what distance is needed to bring the car to rest when it is travelling at 40 km/h?
5. A cart starts from rest at A on the track illustrated in figure 18.8.
   (a) At what point will the cart be travelling with the greatest speed?
   (b) At what point has the cart the greatest potential energy?
   (c) Assuming that the cart constantly loses energy due to friction, where will it eventually come to rest?

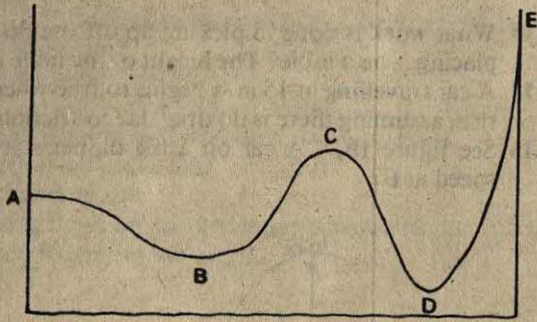


Figure 18.8

19

The invertebrates: animals without backbones

Living things may be divided into two main groups — animals and plants. However, it is not always easy to determine which group a particular organism belongs to. Take the *Euglena* (figure 19.2—(b)) as an example. It is a single-celled organism that can move itself about by means of a flagellum. On the other hand, it is green and can produce its own food by means of chloroplasts. But it has no cell wall. Is it a plant or an animal?

Scientists have classified *Euglena* as an animal, mainly because of the absence of a cell wall. All plants have cell walls; animals do not.

The following three points could be accepted as a definition of an animal as distinct from a plant.

- The cells of animals have membranes; they do not have walls.
- Most animals get their food by eating plants or other animals.
- Most animals can move.

Classification of animals

The famous Greek philosopher Aristotle was perhaps the first to attempt to classify animals. He divided them into two main groups — those with blood and those without blood. Although this basic division was used for two thousand years, it eventually proved unsatisfactory.

In the eighteenth century a new classification was proposed — animals with backbones (the vertebrates) and animals without backbones (the invertebrates). This classification provided a good basis for further subdivision and is still in use today. (See figure 19.1.)

Most vertebrates are well known because they are large. Invertebrates, on the other hand, are generally small animals that escape our notice. (How many invertebrates did you see on your way to school this morning?) But, although they are small, there are many, many more species of invertebrates in the world than there are of vertebrates.

There is great variety among the invertebrates. Some are very beautiful and highly coloured, like the starfish and sea slugs; others are ugly, like the parasites that live in the bodies of other animals. Some of a farmer's or gardener's best friends are among the invertebrates. Think of the importance of insects in pollinating flowers and earthworms in improving the soil. On the other hand, some invertebrates, although small, are quite dangerous. The funnel-web spider and the fly that spreads yellow fever are examples.

In this chapter we shall study seven invertebrate groups — protozoans, sponges, echinoderms, coelenterates, worms, molluscs and arthropods.

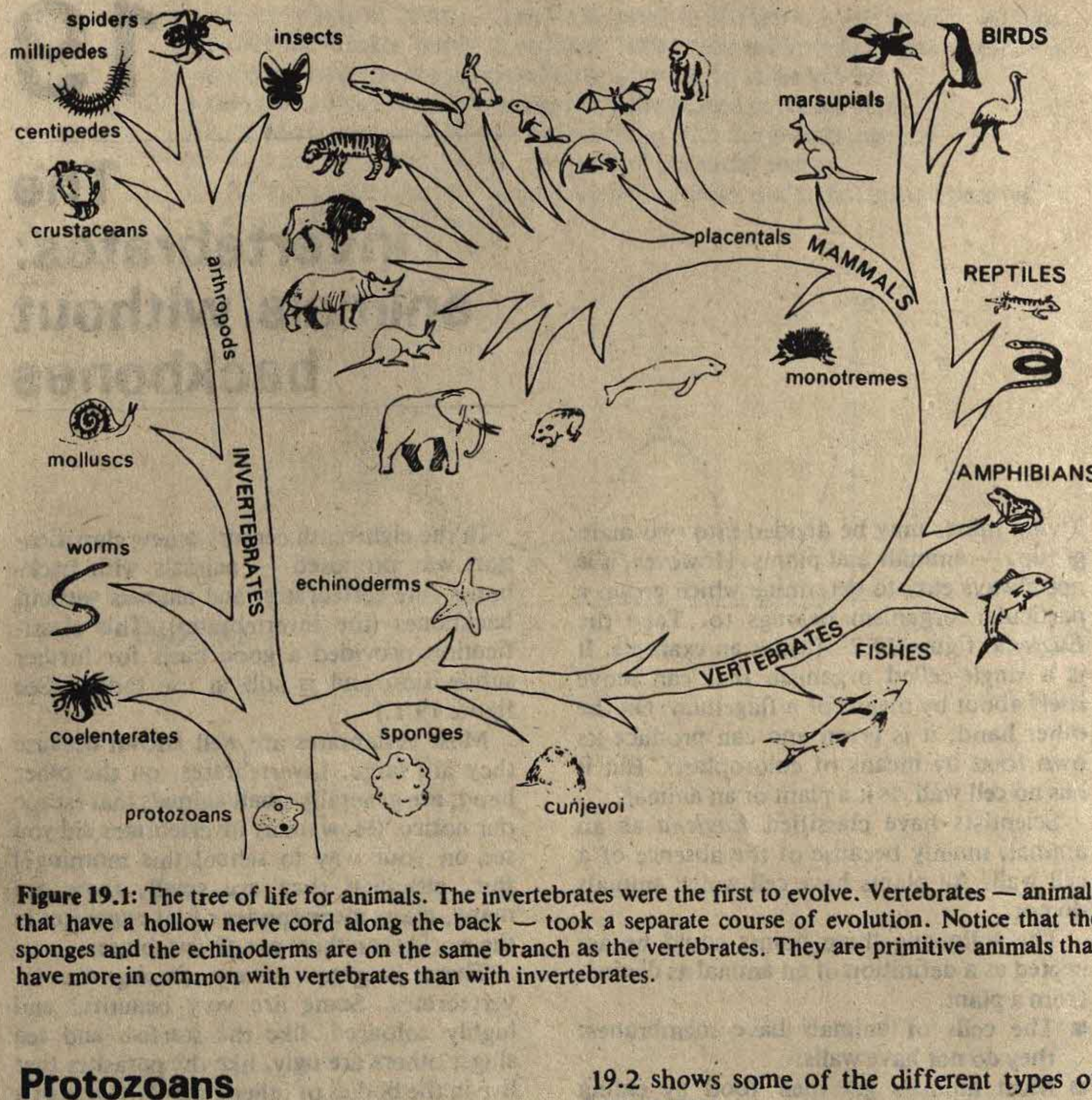


Figure 19.1: The tree of life for animals. The invertebrates were the first to evolve. Vertebrates — animals that have a hollow nerve cord along the back — took a separate course of evolution. Notice that the sponges and the echinoderms are on the same branch as the vertebrates. They are primitive animals that have more in common with vertebrates than with invertebrates.

Protozoans

Protozoans were the first animals to appear on earth. Because they had no hard parts, fossils of early protozoans are rare and poor in detail. Nevertheless, we believe we have enough evidence to say that protozoans first appeared approximately 1000 million years ago.

Protozoans range in size from a few micrometres up to one or two centimetres. They are found in both fresh and salt water, in most soil and also in the tissues and bloodstreams of other organisms. Figure 19.2 shows some of the different types of protozoans.

Protozoans move about in a number of different ways. Some push out part of their protoplasm, some move a whip-like thread about, while others have thousands of hair-like projections that move continually.

Protozoans reproduce by dividing into two. The process is called binary fission. It is illustrated in figure 19.3.

Like all living cells, protozoans respire. The oxygen they require diffuses into the organism. This happens because the cell continually uses oxygen and the concentration

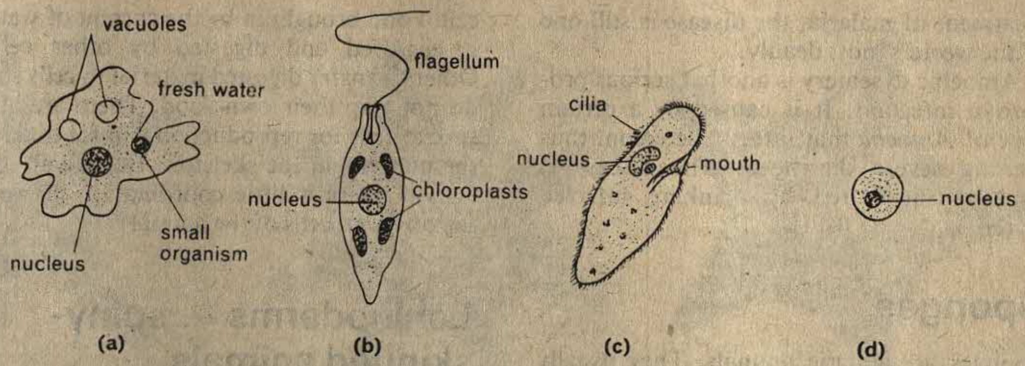


Figure 19.2: Some different types of protozoans.
(a) An *Amoeba* shown engulfing a small organism for food. The organism is gradually digested and absorbed. The vacuoles gradually fill with water absorbed by osmosis. Occasionally the vacuoles contract and expel their liquid.
(b) A protozoan with a whiplike thread, or flagellum. This organism, *Euglena*, possesses chloroplasts. It can therefore make its own food by photosynthesis.
(c) *Paramecium*, a protozoan with thousands of hair-like projections called cilia, which enable it to move.
(d) *Plasmodium*, a protozoan that lives in the bloodstream of its host. It has no way of moving on its own. The disease malaria is caused by a *Plasmodium* infection.

of oxygen is therefore lower inside the cell than outside. Carbon dioxide is continually produced during respiration. The concentration of this gas is therefore higher inside the cell and so it diffuses out of the organism.

Some water-dwelling protozoans possess hard parts. Some build a skeleton of calcium carbonate; others have a skeleton of silica. When the organisms die the tiny hard parts settle out of the water. Many areas of the ocean floor are covered with an ooze consisting of these shells and skeletons. As ooze is compressed it hardens and forms rocks such as limestone and flint.

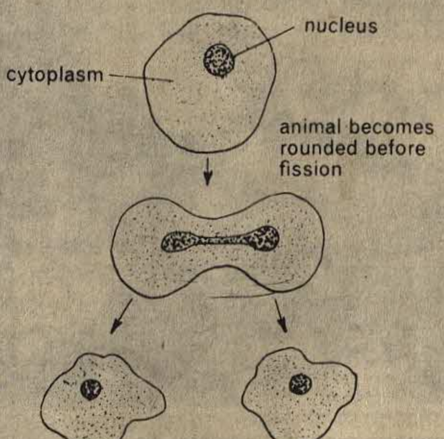


Figure 19.3: Binary fission of protozoan.

Among the protozoans that live within other animals are those living in the gut of the termite. These are necessary for the termite's survival — they digest the wood it eats. Without them the termite would die. Sheep and cattle rely on protozoans in a similar way, to digest the cellulose in the grass they eat.

While some protozoans are useful to other organisms, others cause disease. The disease malaria, for example, is a protozoan infection of humans that destroys many of their red blood cells. The parasite causing the disease reproduces in the human bloodstream and liver and also in the stomach of the *Anopheles* mosquito. When an infected mosquito bites someone, the parasite passes into that person's bloodstream through the mosquito's snout. Although there are now many drugs available for the prevention and treatment of malaria, the disease is still one of the world's most deadly.

Amoebic dysentery is another serious protozoan infection. It is caused by a certain type of *Amoeba* that infects the colon, thus causing severe diarrhoea. The disease is usually transmitted by drinking infected water.

Sponges

Sponges are aquatic animals. They usually live attached to rocks in the sea. Their fibrous skeletons are very absorbent because they contain many holes, or pores. These holes are part of a filter system by means of which the animal gets its food and oxygen.

The sponge is little more than a collection of uncoordinated cells. Each cell carries out some simple activity. Some of the cells lining the pores draw in water by the beating action of a whip-like structure that is part of the cell. Food brought in by the current of water is engulfed and digested by other cells. Others transfer digested material to cells that do not trap their own food. There are also special cells for reproduction and for making the material in the skeleton. Despite all this activity there is little coordination between the different cells of the animal.

Echinoderms — spiny-skinned animals

All echinoderms are marine — they cannot survive in fresh water. They include starfish, sea urchins and brittle stars. Figure 19.5 is a photograph of some starfish or, rather, sea stars. Figure 19.6 (facing page 137) is a colour photo of a sea urchin.

Echinoderms have spiny skins and arms that radiate out from the central part of the body. There are many hollow tubes on the

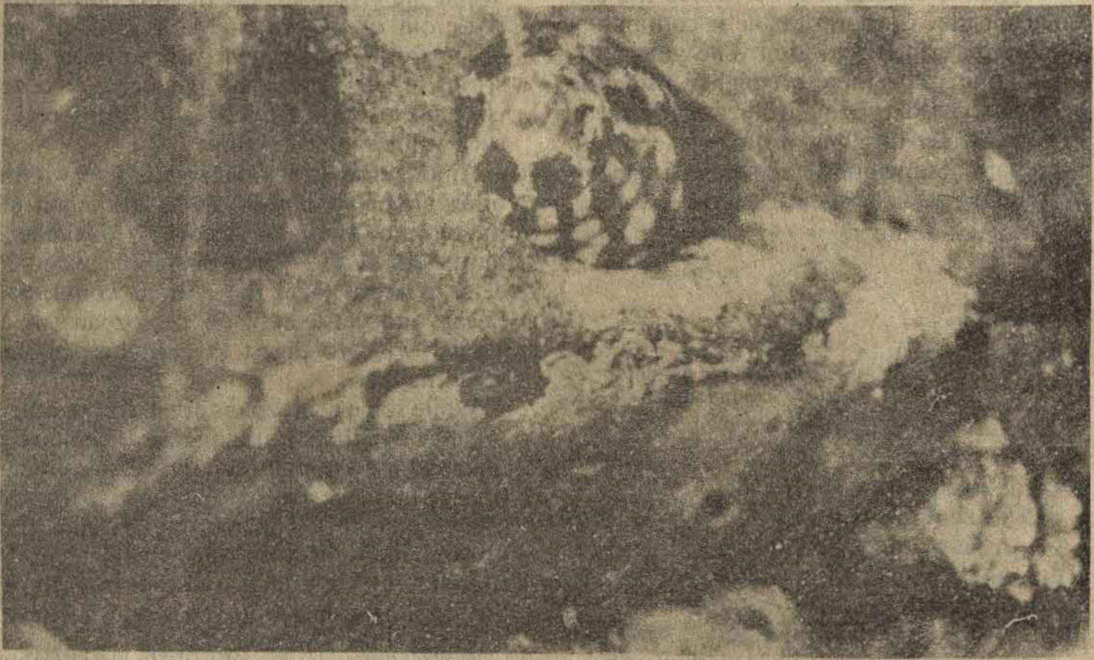


Figure 19.4: A sponge under a ledge in a rock pool. The sponge is a primitive animal. Some of its cells are adapted for drawing in water, some for digesting food and others for reproduction. Despite all this activity, there is very little coordination between the different parts.

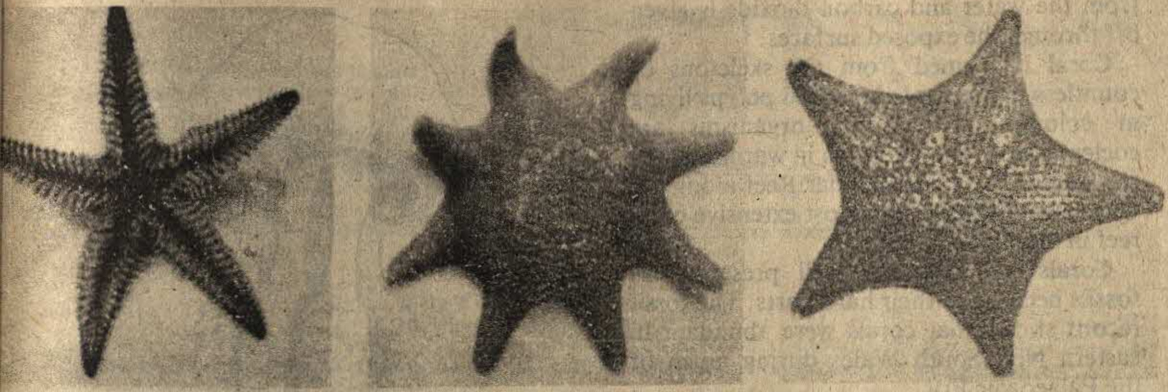


Figure 19.5: Some echinoderms. These are sea stars.

undersurfaces of the arms. These tubes are the means by which the animal moves about, by expelling water from the tubes under pressure.

Like the sponges, many echinoderms can reproduce by the asexual process known as regeneration. If an arm is detached from the animal, a completely new animal grows from the arm. Echinoderms also reproduce sexually by a complex process involving several larval stages.

Examination of the tree of life (figure 19.1) shows that echinoderms are placed on the same branch as the vertebrates. This is because the embryos of echinoderms are very similar to those of primitive vertebrates and not at all like those of other invertebrates.

Coelenterates — cup animals

Coelenterates include jellyfish, sea anemones and coral. (See figure 19.8, facing page 136.) They are very primitive animals — like sponges, they have no organs in their bodies. Coelenterates have soft bodies with a space inside shaped like a cup. This space is the digestive cavity. It has only one opening through which food enters and undigested material leaves.

The food is often live prey, which is caught by tentacles and paralysed by special stinging cells. It is then pulled into the digestive cavity. Cells in the cavity bathe it in digestive juices. This dissolves part of the food and this part is absorbed. Other parts that cannot be digested are passed back out of the cavity through the opening.

Respiration occurs very simply. All the surfaces of the body, both inside and out, are exposed to water. Oxygen is absorbed

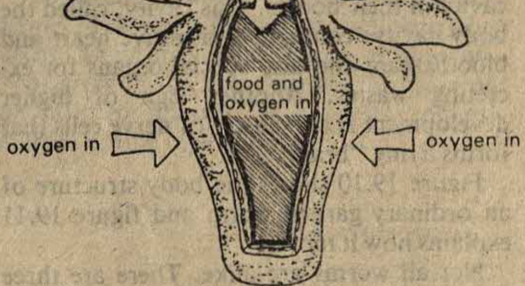


Figure 19.7: Diagram of a typical coelenterate. Coelenterates are primitive animals with neither heart, lungs, veins nor arteries. Materials are absorbed and excreted through the walls of the cells.

from the water and carbon dioxide is given off through the exposed surfaces.

Coral is formed from the skeletons of countless millions of tiny coral polyps living in colonies. These tiny organisms are coelenterates. They flourish in warm shallow sea water. The Great Barrier Reef along the Queensland coast is the most extensive coral reef in the world.

Corals are generally well preserved as fossils because of their hard parts. The fossil record shows that corals were abundant in eastern New South Wales during much of the Palaeozoic Era.

The bluebottle, or Portuguese man-of-war, is another interesting coelenterate. It consists of many individual coelenterates all living together in a floating colony. One of these individuals is an enlarged floating gas bag. From it, long streamers trail through the water. Some of these streamers contain feeding individuals, some contain stinging individuals and others contain individuals that can reproduce. (See figure 19.9.)

Worms

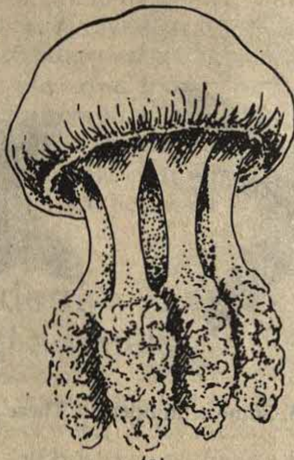
Worms are more highly developed than coelenterates. For example, most worms have two body openings — a mouth and an anus. Coelenterates, on the other hand, have only the one opening to the digestive cavity.

Coelenterates have no organs inside their bodies. Worms, however, have an additional cavity in their bodies. This cavity, called the body cavity, contains a primitive heart and bloodstream and also special organs for excreting wastes. Another sign of higher development is the cluster of nerve cells that forms a tiny "brain"

Figure 19.10 shows the body structure of an ordinary garden worm and figure 19.11 explains how it moves.

Not all worms are alike. There are three main groups:

- flatworms
- roundworms
- segmented worms.



(a)

(b)

Figure 19.9: Two coelenterates. (a) A common variety of jellyfish. The animal moves through the water by contractions of its body. Tentacles around the opening to the digestive cavity contain stinging cells for capturing prey. (b) The bluebottle — a floating colony of separate individuals. Some of these individuals are specialized to obtain food, some to reproduce, and others to capture prey. The floating bag is an individual specialized to support the colony.

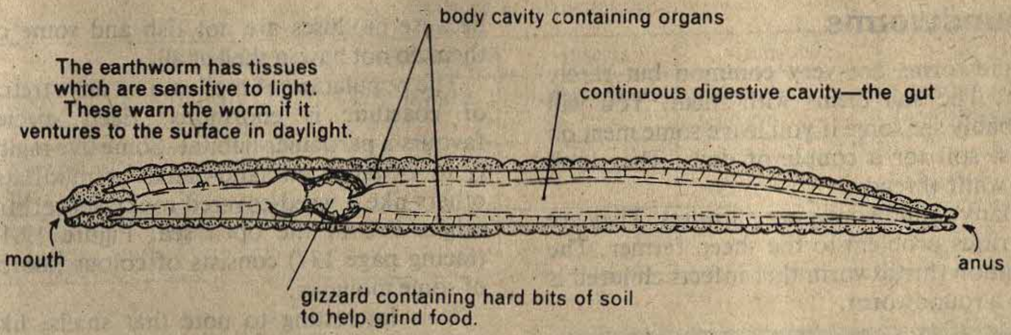
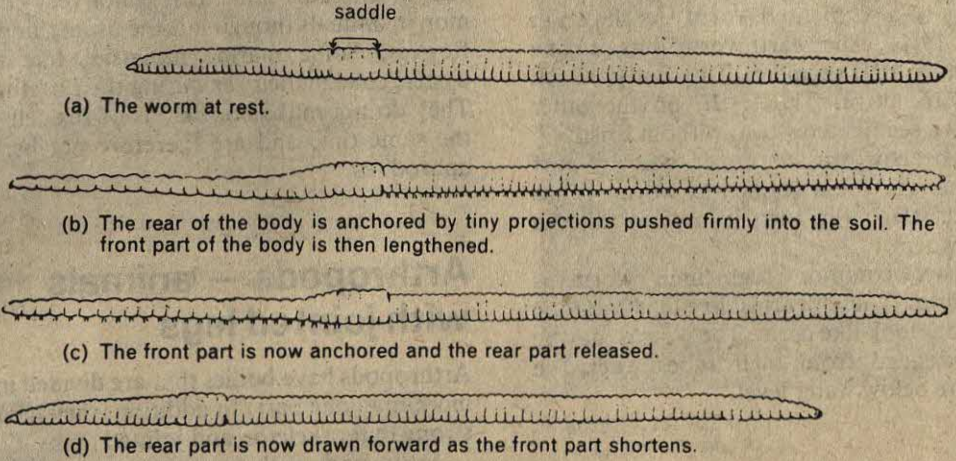

body cavity containing organs
The earthworm has tissues which are sensitive to light. These warn the worm if it ventures to the surface in daylight.
continuous digestive cavity—the gut
mouth
anus
gizzard containing hard bits of soil to help grind food.

Figure 19.10: Section showing the general arrangement of the gut and body cavity of an earthworm.



(a) The worm at rest.

(b) The rear of the body is anchored by tiny projections pushed firmly into the soil. The front part of the body is then lengthened.

(c) The front part is now anchored and the rear part released.

(d) The rear part is now drawn forward as the front part shortens.

Figure 19.11: How an earthworm moves.

Flatworms

Flatworms are the most primitive kind of worm. Many are free-living (i.e., not living in or on another animal) and may be found in streams, ponds, the soil and at the seashore. Turning over a few rocks in the intertidal zone on the seashore will sooner or later expose a flatworm. It will be a flattened leaf-like animal and will glide either towards the water or under another rock. Figure 19.12 is a drawing of a flatworm.

Tapeworms and liver flukes are also flatworms. They are harmful parasites commonly found in rural districts.

The hydatid tapeworm lives in the intestine of a dog. Eggs pass out with the faeces. These may infect sheep or humans. Cysts grow in the liver, muscles or brain of the infected animal. These cysts contain millions of tiny tapeworms.

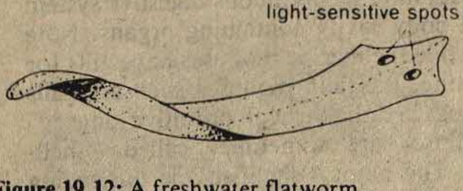


Figure 19.12: A freshwater flatworm.

Roundworms

Roundworms are very common but rarely seen. The soil teems with them. You will probably see some if you leave some meat on moist soil for a couple of days. They look like white threads.

Many roundworms are parasites. They are a serious problem to the sheep farmer. The common threadworm that infects children is also a roundworm.

Segmented worms

The common earthworm is the best known example of a segmented worm. As shown in figure 19.11, the earthworm has a few bristles on each segment of its body, which help it to move. The leech, on the other hand, is a segmented worm without bristles.

The beachworm, used for bait by surf fishermen, is also a segmented worm. It has many bristles — in fact, it is often called a bristle worm.

Another common segmented worm is *Galeolaria*. These worms live in limestone tubes that look like coral. The worms may be seen extended from their tubes when the tubes are below water level.

Molluscs — soft-bodied animals

The molluscs include the oyster, pipi, periwinkle, octopus and garden snail. Molluscs have a soft continuous body and most have a shell. This shell is sometimes internal, as in the case of the octopus. The muscular foot that acts like a suction pad is characteristic of all molluscs.

Like the more highly developed worms, molluscs have a continuous digestive system and a body cavity containing organs. Note that while the marine molluscs have gills for breathing, the land molluscs such as snails and slugs breathe through primitive lungs.

Molluscs are sometimes called "shellfish". The name "shellfish" is misleading because molluscs are not fish and some of them do not have a shell at all.

The population of molluscs on any stretch of coastline is enormous. Each species favours a particular habitat. Some live mainly in estuaries on sand-banks or mudflats; others like a weed-covered rocky shore; still others live in the open sea. Figure 19.13 (facing page 137) consists of colour photos of some molluscs.

It is interesting to note that snails, like some worms and coelenterates, are normally hermaphrodites. This means that a single individual makes both male and female sex cells at the same time. This is not very common in animals though it is the usual thing in flowers. Some marine molluscs, like the oyster, change their sex during their lifetime. They do not make both kinds of sex cells at the same time and are therefore not hermaphrodites.

Arthropods — animals with jointed legs

Arthropods have bodies that are divided into more than one part. In addition, they have a strong outer skeleton and jointed limbs.

Arthropods include crustaceans, spiders, insects, centipedes and millipedes. Table 19.1 sets out the main differences between these groups and figures 19.14 to 19.18 show an example of each kind.

The outer skeleton of arthropods is rigid and the joints are worked by internal muscles. An outer skeleton, called an *exoskeleton*, has a number of advantages. It protects the soft body from injury; it gives support to the body; and it is waterproof. Being waterproof prevents the body from drying out. (Compare the effect of sunshine and dry air on a millipede and on an earthworm — the worm soon dries out and dies.)

As the skeleton is made from non-living material, it does not grow as the animal increases in size. Therefore the skeleton must periodically be shed and replaced. This is called moulting.

Table 19.1: Arthropods

	Crustaceans	Spiders	Insects	Centipedes	Millipedes
Body	mostly in two parts	in two parts	in three parts	many flat segments	many round segments
Number of legs	commonly ten	eight	six	one pair per segment	two pairs per segment
Method of breathing	gills	book lungs	tubes in body called tracheae		

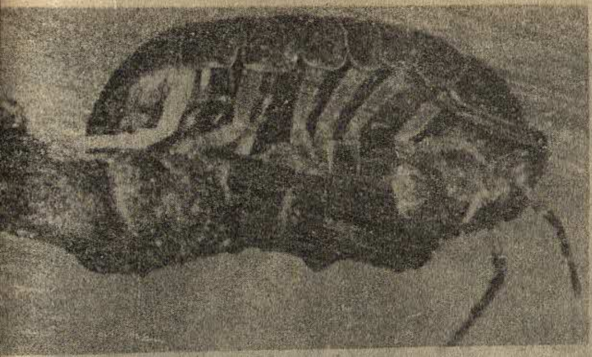


Figure 19.14: An arthropod — a crustacean (a slater).

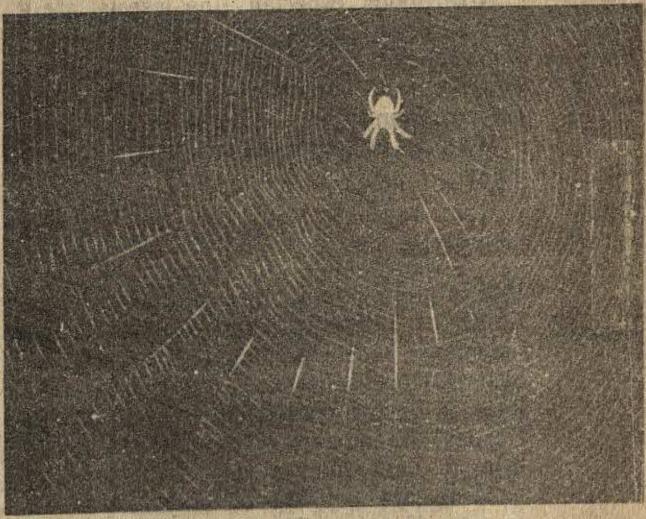
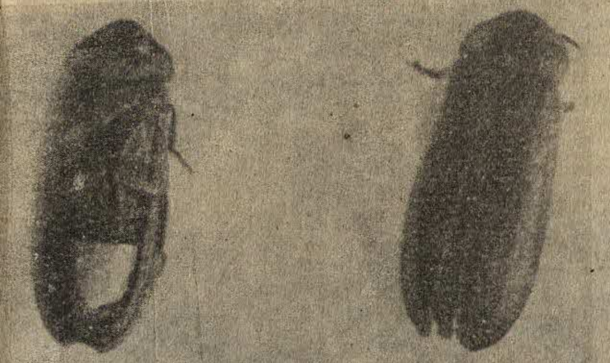


Figure 19.15: An arthropod — a spider. This web was woven in a few hours.



◄ **Figure 19.16:** An arthropod — an insect (the firefly). Notice the light-coloured patch on the abdomen, which gives out pulses of light.

Figure 19.17: The centipede has only one pair of legs on each body segment.

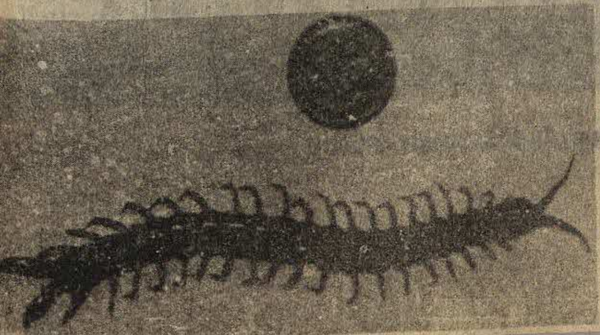
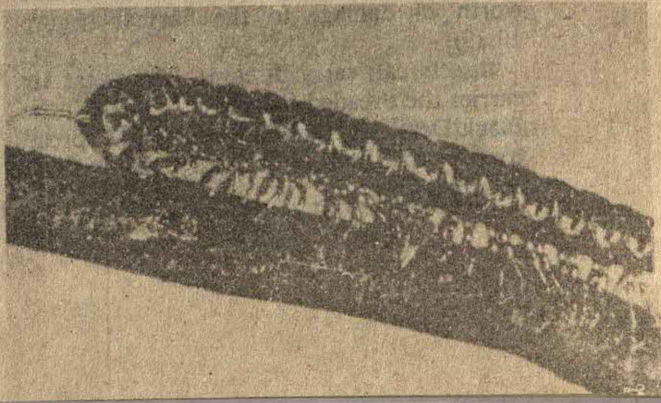


Figure 19.18: An arthropod — a millipede.



The jaws of an arthropod work from side to side and not up and down like those of humans. Next time you visit an aquarium or rock pools on the coast, try to watch a crab feeding.

Because of the more active life of the arthropods, their nervous system has become more elaborate than those of the coelenterates and worms. The eyes especially have become highly complex and efficient organs.

Arthropods, especially the insects, are a very successful group of animals. Their success is shown by the vast number of species and the wide variety of habitats in which they are found.

We shall now examine the insects in more detail.

Insects

Insects are a fascinating group of animals. Think of caterpillars and the destruction they cause and then compare them with the beautiful butterflies they change into. The bites of fleas and mosquitoes, the noise of cicadas, the industry of the ant and bee all bring insects to our notice.

There are 850 000 different kinds, or species, of insects. The actual insect population on earth would be countless billions. Insects are so successful that they are a constant threat to the human species — in some cases, even to human survival. It is not numbers but intelligence that enables the human race to be dominant.

The plague locust has a formidable history of devastation. Whole crops have been eaten and, as a result, many people have died of starvation. In Australia we are constantly on the alert for hatchings of grasshoppers in wheat-growing areas. If unchecked, the grasshoppers can cause millions of dollars worth of damage to the harvest (figure 19.19).

Insects can carry diseases. The tsetse fly carries the dreaded "sleeping sickness"; the Black Death of the Middle Ages was spread by lice; and mosquitoes carry yellow fever and malaria.

Some insects actually attack animals. An example is the blowfly. It lays its eggs in the wool of sheep. On hatching, the larvae move down the wool to the skin, on which they begin to feed. Unless treated they will eat right into the body of the living sheep.

The list of insects that live in plants or plant products is almost endless. Fruit-fly maggots in fruit, weevils in stored wheat and other grains, white ants in timber and wood wasps in pine trees are just a few examples.

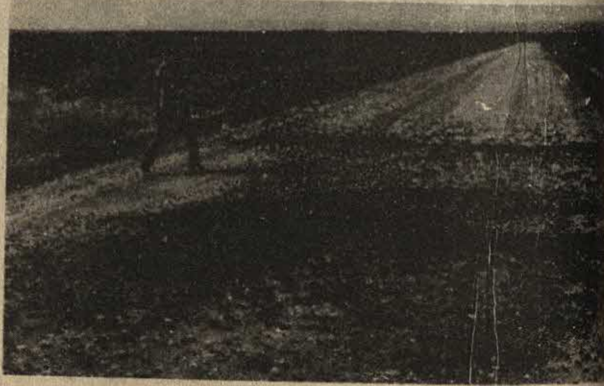


Figure 19.19A: Band of locust nymphs.

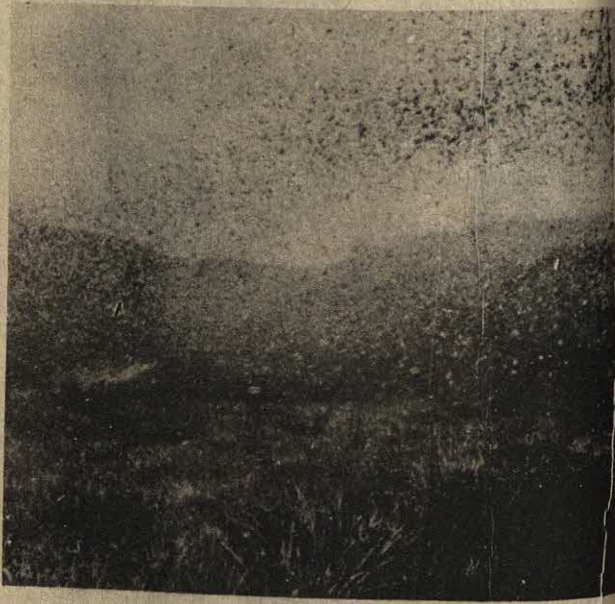


Figure 19.19B: Locust swarm.

We know, of course, that not all insects are harmful. Insects are essential for the pollination of most flowers, and many insects destroy other, harmful, insects. The ladybird, for example, eats aphids, one of the most troublesome insects in vegetable and flower gardens. Figure 19.20 shows a fruit-fly wasp, *Opius longicaudatus*, depositing eggs in a banana. When the eggs hatch, the larvae of the wasp eat the maggots of the fruit-fly.

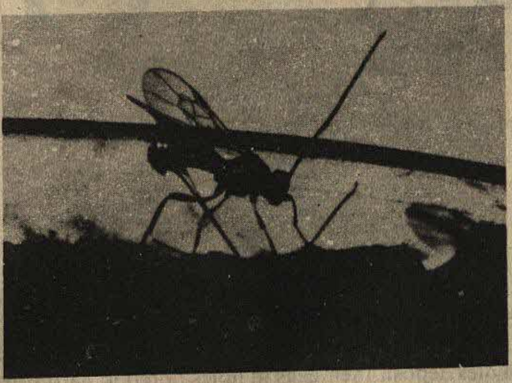


Figure 19.20: The fruit-fly wasp — an example of a very useful insect. This photo shows it depositing eggs in a banana. The larvae from these eggs will eat any fruit-fly maggots in the banana. (Photo courtesy Division of Entomology, CSIRO)

Metamorphosis. In some animals, the body undergoes marked changes of form during the life cycle. The silkworm is an example. (See figure 19.21.) It starts off life as a grub. Then it spins a cocoon around itself. While in the cocoon it changes into a moth, which eventually emerges and lays its eggs. From the eggs hatch the grubs, and so on. Such a series of changes is called metamorphosis.

Most insects undergo metamorphosis during growth and development. The silverfish is an exception. It hatches out into a small insect that is a replica of the adult.

There are two kinds of metamorphosis — incomplete and complete.

Incomplete metamorphosis. The grasshopper is an example of an insect that has an incomplete metamorphosis in its life cycle. (See figure 19.22.) There are three stages — egg, nymph and adult. Other insects that have an incomplete metamorphosis are cockroaches, earwigs, lice, termites, aphids and thrips, to mention only a few.

Complete metamorphosis. In the life cycle of many insects, the stage that hatches from the egg is completely different from the adult. It is called a *larva*.

There are a number of different kinds of larvae produced by different groups of insects. The larva of a butterfly or moth is called a caterpillar; a fly larva is called a

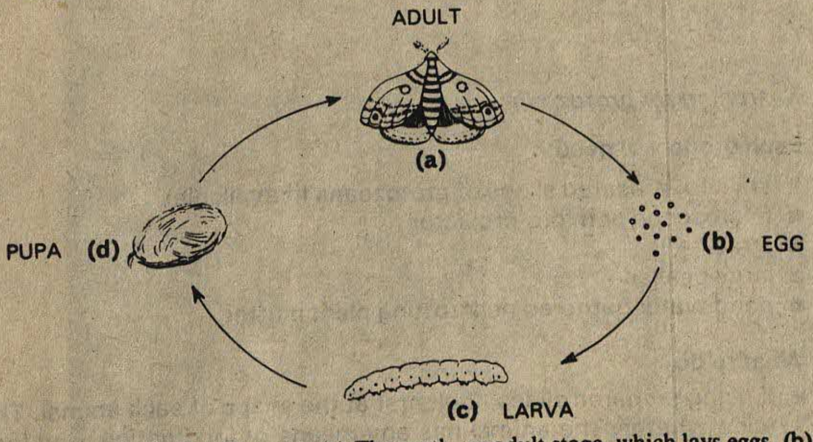


Figure 19.21: The life cycle of a silkworm. (a) The moth, or adult stage, which lays eggs. (b) The tiny eggs, which are about 1 mm in diameter. (c) The silkworm grub, which is a voracious eater. It is fed on mulberry leaves and grows from 1 mm to 40 mm long during a period of several weeks. (d) The cocoon. The grub secretes long strands of silk to make the cocoon around itself. While in the cocoon it changes into a moth.

maggot; the larvae of wasps and bees are grubs and the larva of the mosquito is called a wriggler.

The larval stage is the feeding and growing stage of the insect. Growth is rapid and involves several changes of skin. When fully grown, the larva turns into a pupa. (See figure 19.21.) This is a resting period during which the larva changes into the adult. When the adult emerges from its pupal case or cocoon, it is fully developed and ready to carry out its main function — reproduction. The life cycle of such an insect is truly a remarkable natural phenomenon.

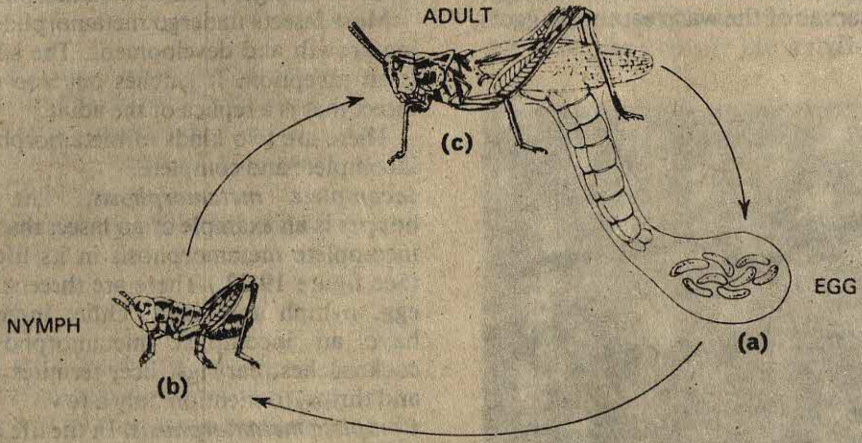


Figure 19.22: The life cycle of a grasshopper. (a) The females deposit their eggs in holes bored in hard soil by means of horny plates at the end of the abdomen. The eggs need both warmth and moisture for hatching. (b) Upon hatching, the young insects, known as nymphs, make their way to the surface of the soil. They are somewhat like their parents except that they have no wings. As they grow, their skin, which does not grow with them, is cast off. This happens five or six times. (c) When the last skin is cast off the wings of the adult appear.

EXPERIMENT 19.1 *Searching for protozoans*

Each group will need:

- stained, prepared slides of protozoans (if available)
- microscope or micro-projector
- straw
- large beaker
- pond water gathered near rotting plant matter

What to do

- If using prepared slides, look first at the shape of each animal. Then determine whether the animal has any means of locomotion, and look for the nucleus.
- If using the straw and pond water, mix the two in a beaker and take samples over a period of two weeks. Each time look at one drop of water from the beaker through the microscope.

Question

19.1 Did you see any animals moving about in the water? How did each one move? Draw a quick sketch of the animals and try to identify each type of movement. (Remember that you may also see algae in the water.)

EXPERIMENT 19.2

Identifying invertebrates

The class will need:

- a collection of live and preserved invertebrates (see appendix 1 for ways of preserving specimens)
- hand lens
- binocular microscope

What to do

- Look at each preserved specimen in turn. First, try to place the specimen in one of the major groups — sponge, echinoderm, coelenterate, worm, mollusc or arthropod. Record your observations and conclusions in a table like the one on page 228.

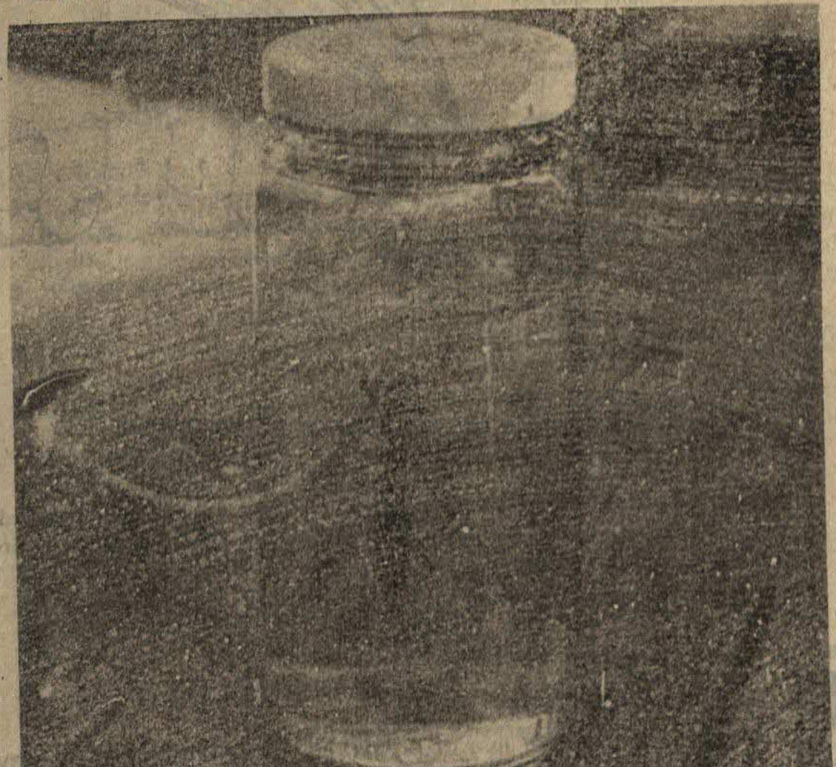


Figure 19.23: Showing the method of preserving an invertebrate in a mixture of alcohol and water.

- Next, examine the live specimens and classify them in the same way, always recording your results.
- Finally, try to name each specimen examined. You will need help in this, either from your teacher or from books, such as the Periwinkle books by John Child (Melbourne: Lansdowne Press, 1968).

Specimen no.	Description of features	Group	Name of specimen

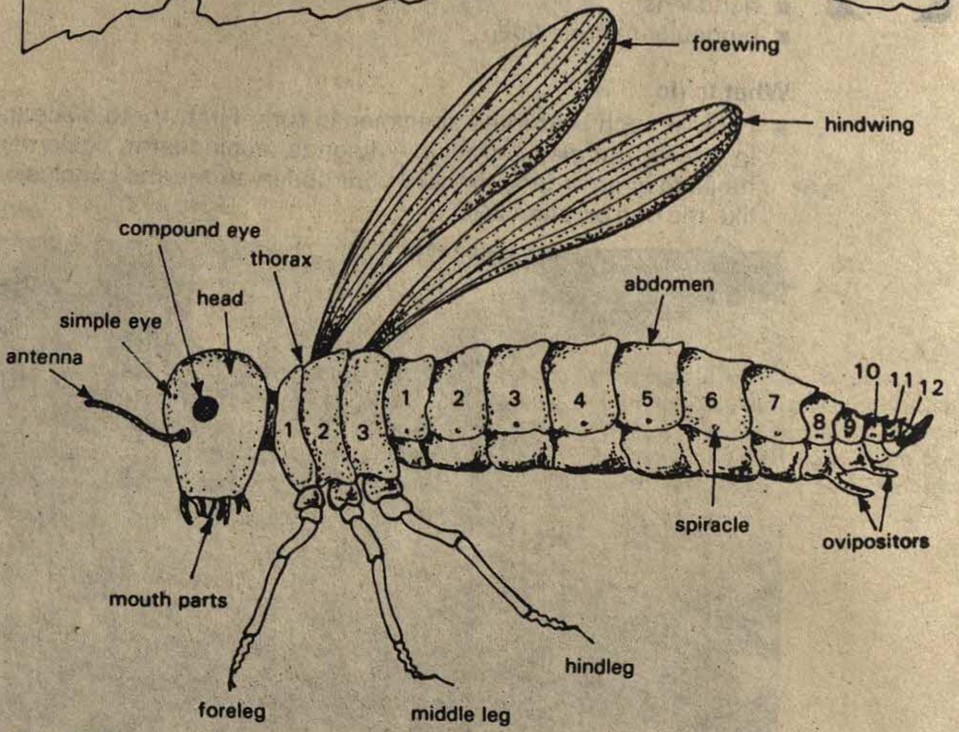


Figure 19.24: A typical insect. The wings on the near side have been removed. The number of segments in the abdomen may vary. The hind legs of hopping insects are much larger than the other two pairs.

EXPERIMENT

19.3

Investigating arthropods

Each group will need:

- specimens, either live or preserved, of such animals as prawns, crabs, slaters, silverfish, ants, spiders, ticks, fleas, grasshoppers, cockroaches, flies, moths, butterflies, centipedes and millipedes
- hand lens
- binocular microscope

What to do

- Look at each specimen in turn. Note the number of main body segments and count the legs. Record these and other observations in a table like the one below.

Name of animal	No. of body segments	No. of legs and where attached	No. of wings and where attached	No. of eyes	No. of feelers

Question

19.2 Choose two of the arthropods that particularly interest you. Find out
- (a) what kind of food each one eats
- (b) how it obtains its food and how it digests it
- (c) how it obtains oxygen
- (d) how it excretes waste material
- (e) how it moves about.

EXPERIMENT

19.4

Studying life on a rock platform

What to do

- Figure 19.25 shows some of the animals and plants found on a rock platform. The animals are arranged in groups according to the food they eat. Study the figure carefully before your excursion to the rock platform.
- In your excursion notebook, list the names of the animals in the figure. Next to each write the name of the group to which it belongs.
- Choose a rock pool on the platform. Working in pairs, examine the organisms living in the pool.
- Draw up a table similar to the one below and record your observations. In the "adaptations" column, record such things as the methods used for resisting the battering of the waves and for resisting drying out. Draw rough sketches of any organism you have difficulty identifying.

Name of organism	Number in pool	Method of obtaining food	Adaptations

- Some organisms are adapted to more successful survival in certain zones of the rock platform. (See figure 19.26.) These organisms are called indicator organisms because they indicate a particular zone. At low tide, walk from the top platform to sea level and try to identify the indicator organisms shown in the figure.

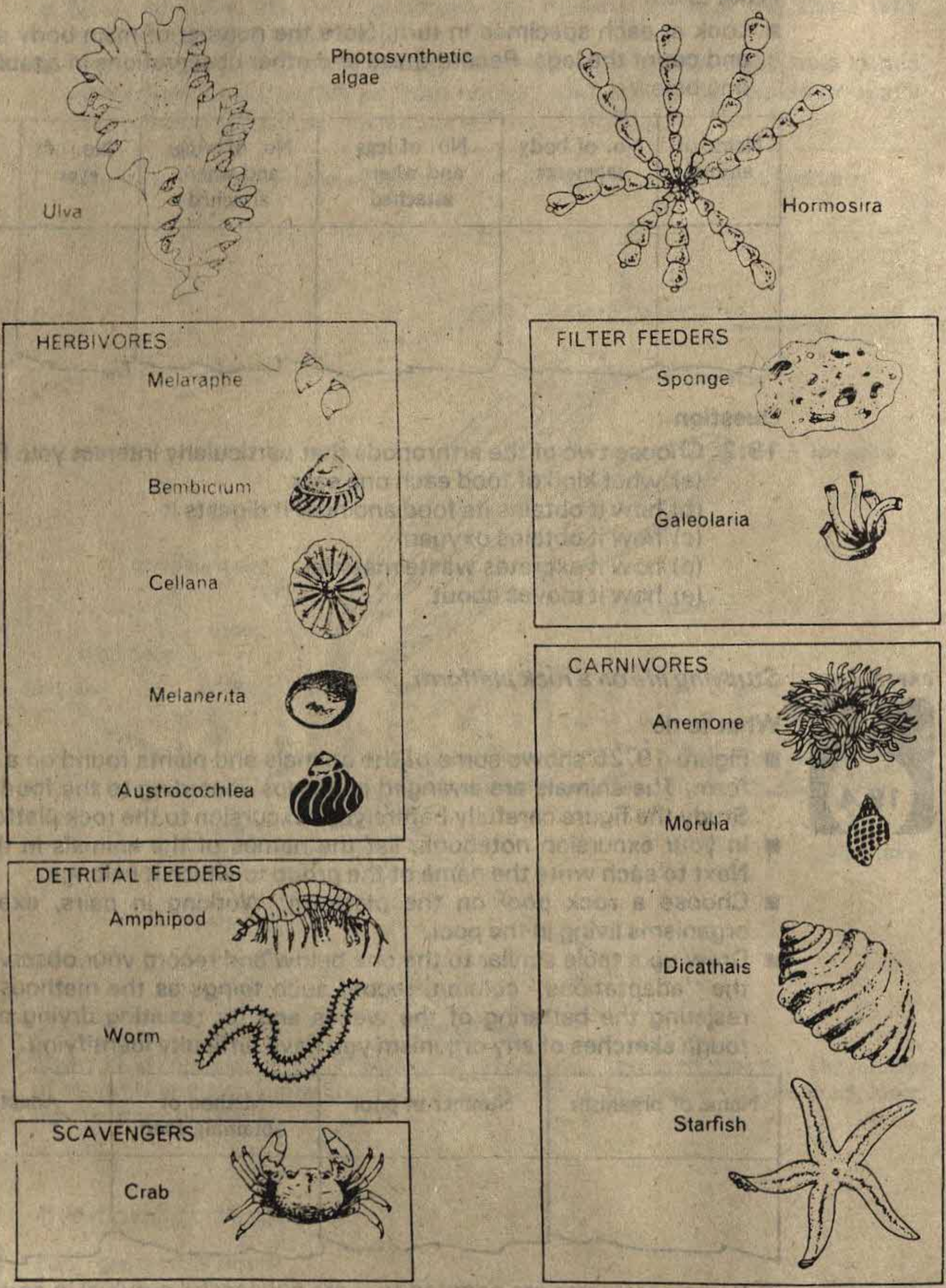


Figure 19.25: Some animals and plants found on a rock platform.

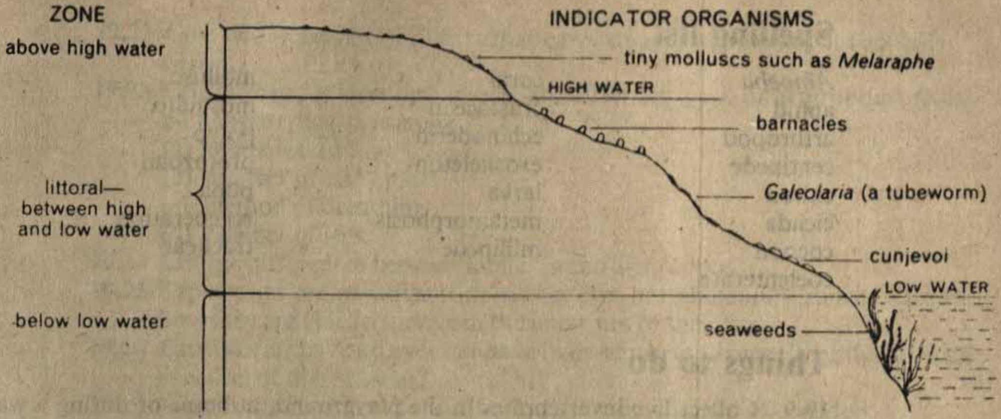


Figure 19.26: Zones of the rock platform and their indicator organisms.

Questions

19.3 Explain the meanings of the following terms: herbivores, carnivores, filter feeders, detrital feeders, scavengers.

19.4 What is the littoral zone?

19.5 The indicator organisms above the littoral zone are tiny molluscs. Explain why these tiny molluscs do not dry out and die.

19.6 The indicator organisms in the littoral zone are all filter feeders. Explain why these organisms could not survive above the littoral zone.

19.7 Make up two food chains for organisms living on a rock platform.

19.8 Which of the filter feeders in the littoral zone has the most efficient filtering system? Give a reason for your answer.

The invertebrates

- Protozoans are single-celled and aquatic or parasitic.
- Sponges are simple aquatic animals whose fibrous skeletons contain many pores.
- Echinoderms are marine and have a spiny skin. They have arms radiating out from the central part of the body.
- Coelenterates are mostly marine and have soft hollow bodies with tentacles.
- Worms are aquatic or terrestrial and have flat or cylindrical muscular bodies. Some are segmented.
- Molluscs are mostly marine and have soft bodies with a muscular foot. Many have a shell.
- Arthropods live in many different environments and have segmented bodies with a strong outer skeleton. They also have jointed limbs.

Spelling list

Amoeba
aphid
arthropod
centipede
chiton
cicada
cocoon
coelenterate
coral
crustacean
echinoderm
exoskeleton
larva
metamorphosis
millipede
mollusc
mosquito
polyp
protozoan
pupa
regeneration
tracheae

Things to do

19.9 Collect live invertebrates in the playground, at home or during a walk in the bush. You will need a pocket knife, a wet brush, tweezers, gloves and bottles of methylated spirits. Lay baits such as bread, meat or sugar in an open dish. Look under logs and rocks. Look in pools. Classify your specimens and name each one, if possible. Try to collect only one of each kind of animal.

19.10 Tie a piece of string to a lump of meat. Leave it in a pond or slow-moving shallow stream for a day or so, then take it out and collect any animals on it. Name each kind of animal found on the meat.

19.11 Bury a piece of meat in moist soil in the garden. After a couple of days, carefully dig it up and examine any animals on it. You may need a binocular microscope to do this.

19.12 Study the life cycle of an insect you are interested in. If you choose a leaf-eating insect, find out what kind of plant it feeds on. Start from any one of the stages of its life cycle. Keep the animal in a shoe box and provide fresh leaves for the caterpillar when it hatches.

19.13 Obtain some mealworms from a pet shop. Keep them in a jar with moist oatmeal. Observe them over a period of several weeks, noting any changes that occur. Feed the mature mealworms on grated raw carrot.

More questions

19.14 What are some of Australia's dangerous spiders?

19.15 Are any echinoderms useful to humans? If so, in what way are they useful?

19.16 What molluscs are useful to humans?

19.17 Choose one invertebrate that interests you. Write an account of it, describing such things as habitat, food, adaptations to life in its habitat, effects on humans and other animals.

19.18 What is the origin of the oozes covering much of the ocean floors?

19.19 Give one example of a useful protozoan and one example of a disease-causing protozoan.

19.20 The following is a list of invertebrates. Name the group to which each belongs and give a reason for placing it in that group.
Octopus, crayfish, insect, earthworm, sea anemone, *Amoeba*, bluebottle, liver fluke, spider, oyster, starfish, limpet and barnacle.

19.21 Compare the ways in which worms and molluscs move.

19.22 Give two examples of insects that carry disease. Name the disease each carries.

19.23 Crustaceans, spiders and insects are different types of arthropods. Compare these types, discussing
- (a) where found
- (b) number of body parts
- (c) method of breathing
- (d) number of legs.

19.24 List the differences between molluscs and arthropods.

19.25 Tapeworms are parasites with neither eyes nor alimentary canals. Explain how they are able to survive in the intestines of their host.

19.26 Earthworms have no eyes but have light-sensitive tissues. What is the main function of these tissues?

19.27 What is the function of the silk glands in the abdomen of a spider?

19.28 Spiders digest their food outside the body. How do they do this and how do they take in the digested food?

19.29 List some of the crustaceans that are of economic importance because of their value as food.

19.30 The octopus has an internal shell. Why is this not called a skeleton?

19.31 Give reasons to support the statement: "Molluscs have evolved further than coelenterates."

19.32 *Amoeba* living in fresh water continually absorb water and store it in vacuoles. Explain
- (a) why this absorption occurs
- (b) how the *Amoeba* expel this water
- (c) why *Amoeba* living in the sea do not absorb water.

19.33 Explain why coelenterates are able to survive without a heart.

19.34 Bacteria, like protozoans, are single-celled organisms. Why are they not classified as protozoans?

Test yourself (chapter 19)

Write the answers to questions 1 to 9 in your workbook.

1. Name two protozoans that can move about.
2. Name three species of coelenterates.
3. Name three molluscs with only one shell.
4. Name three molluscs with two shells.
5. Name two molluscs with tentacles.
6. Name the five classes of arthropods.
7. From the list of arthropods in the box, pick out
   - (a) the insects
   - (b) the crustaceans

cockroach, flea, bee, slater, scorpion, grasshopper, tick, tapeworm, sponge, ant, red-back spider, lobster, oyster, prawn, mosquito

8. The octopus, snail and slug all belong to one group. Name the group.
9. Name two features that a grasshopper and a crab have in common.

Choose the best answer to each of questions 10 to 13 and write its letter in your workbook.

10. Which of the following animals is most closely related to the sea anemone?
    (a) crab
    (b) sea urchin
    (c) slug
    (d) jellyfish.
11. Of the following, the two animals *most closely* related are
    (a) bat and fly
    (b) jellyfish and starfish
    (c) snake and worm
    (d) whale and horse
    (e) emu and kangaroo.
12. A grasshopper is better adapted to life in dry places than an earthworm because a grasshopper
    (a) has an outer skeleton
    (b) lays eggs
    (c) eats plants
    (d) breathes air through tubes.
13. Biologists speak of insects as a highly successful group of animals. The main reason for this is:
    (a) There are more insects than humans.
    (b) Insects have a high rate of reproduction.
    (c) Insects have a protective outer skeleton.
    (d) Insects are adapted to more environments than other animals are.

Read the following story to answer questions 14 to 18.

A student found a small animal on the trunk of a tree. He noticed that it had six legs, two eyes and long feelers. He wondered if it was an insect. He then compared the animal with other animals he knew were insects. He found that the animal had many features in common with known insects. He said the animal was probably an insect.

Study the items 14 to 18 below and write
"A" if it is *a problem to be solved*
"B" if it is *the result of observation*
"C" if it is *a conclusion*
"D" if it is *a method of solving a problem*
"E" if it is *a simple observation*.

Items

14. He saw it had six legs, two eyes and long feelers.
15. He wondered if it was an insect.
16. He compared it with other known insects.
17. He found that the new animal had many features in common with the known insects.
18. He said the animal was probably an insect.

20

Plants

In earlier chapters in this book we talked about flowering plants. But flowering plants are only one of a number of different classes of plants, ranging from seaweeds to pine trees. In this chapter we discuss these other kinds of plants.

The earth is more than 4000 million years old. For most of this time there was no life at all on earth. It was not until about 1000 million years ago that the first plants appeared. The evidence on which this statement is based exists in the fossils that are occasionally found in very ancient rocks. These fossils indicate that the first plants were algae.

Algae

Algae are primitive non-flowering plants that have neither roots, stems, leaves nor flowers. Many algae seem to have changed very little since they first appeared. They are truly a record of primitive life. Some are very small organisms; others, such as the seaweeds, are large.

Figure 20.1 shows some freshwater algae magnified about 500 times. The brown slime on plant leaves in a freshwater pond or aquarium contains algae such as these. You will notice that some consist of one cell only, some live together in colonies, and others arrange themselves end to end in long filaments. Experiment 20.1 is an examination of this third kind of algae.

Altogether there are about 15 000 different species of algae, which may be classified into four separate groups.

Blue-green algae are found in both fresh and salt water and also in the soil. Some are important in maintaining the fertility of the soil.

Green algae are mainly freshwater forms but some are found in salt water. Sea lettuce (see figure 20.2b, facing page 136) is an example of marine green algae.

Brown algae are almost entirely marine. They are usually found deeper than green algae. The giant seaweeds washed up on beaches after storms are an example of

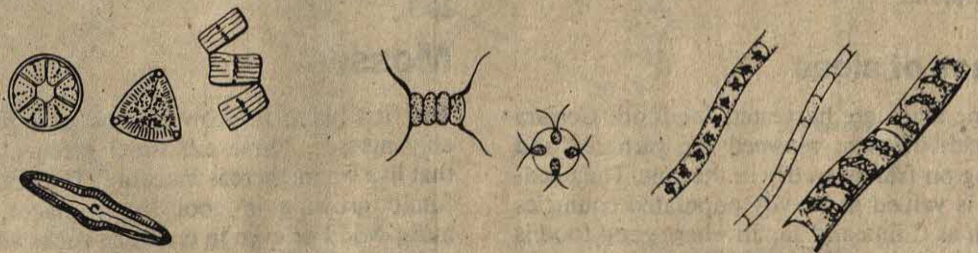


Figure 20.1: Some freshwater algae magnified about 500 times.

brown algae. King Neptune's beads (figure 20.2a, facing page 136) are another example. *Red algae* are also marine and make up the largest group. Figure 20.2c (facing page 136) shows a type found in coastal rock pools.

In spite of the variety of colours, all algae possess chlorophyll and therefore make their own food. As sunlight is needed for photosynthesis, algae are never found growing at great depths in the ocean. Experiment 20.2 is an investigation of brown seaweed that shows that it contains chlorophyll.

Reproduction in algae

Most algae, like many other kinds of plants, can reproduce both sexually and asexually. In asexual reproduction, pieces of plants, or even single cells, become detached from the parent and develop into new individuals. Pairs of sex cells at no stage unite to form a zygote.

Hormosira, known as King Neptune's beads or Neptune's necklace, is an exception — it can only reproduce sexually. In *Hormosira* there are separate male and female plants. The "beads" of both sexes contain small cavities scattered over the surface. The cavities on the male plants produce sperm and those on the female plants produce eggs. At low tide, eggs and sperm are washed out of the cavities into the water. Large numbers of sperm swim to each egg which, however, is fertilized by only one of them. The rest of the sperm swim away. The fertilized egg, the zygote, is only a single cell. It becomes attached to a rock and eventually grows into a new plant.

Uses of algae

Some algae are harvested for food. Certain species of giant seaweed are gathered and hung on frames to dry in the sun. The product is valued in heavily populated countries such as China and Japan where good food is scarce. It is easy to imagine that as world population increases edible seaweeds could become more and more important as a source of food.

Figure 20.3: Harvesting kelp in Tasmania. (Photo courtesy *Hobart Mercury*)

Algae are also used as fertilizer and for manufacturing algin. This is a substance used in the commercial preparation of icecream. It is also a raw material in the manufacture of wrapping foils. (See figure 20.3.)

Mosses

The first plants to grow on land were probably mosses. These are small green plants that live where there is moisture. They can be found growing in cool shady places, on moist wood or even in cracks in rocks where water may collect.

Mosses usually grow packed together in tufts. They are attached to the ground by fine hairs growing from the stalk. These are called rhizoids; they are not true roots. Mosses do not have conducting tissues as the more highly evolved plants do. Instead, water and nutrients move through the plant from one cell to the next by absorption. Mosses do not have true leaves and stems.

Experiment 20.3 is an examination of a moss plant.

Reproduction in mosses

Like algae, mosses can reproduce either sexually or asexually.

In sexual reproduction in some species of mosses, sperm and eggs are produced from the same plant. In other species, sperm and eggs are produced by separate plants. These are called male and female gamete plants.

Figure 20.4 shows the sequence of events in the second group of species. The sex organs are at the tips of the plants, as shown. When conditions are damp enough, sperm are released from the male organ. They swim through water to the egg cell in the female organ and fertilize it. The embryo that results actually grows out of the female sex organ. When the new plant is mature it produces spores in a capsule at its tip. (See figure 20.5.)

The gamete plant and the spore plant of moss should not be thought of as separate plants. Rather should the spore plant be regarded as a sort of primitive "flower" on the female plant.

When the spore capsule is ripe, the lid falls off it and thousands of tiny spores are released. Each spore is a single cell (the first cell of a new plant), protected by a shell. Its chances of growing into a new plant are slight because, unlike a seed, it carries practically no food. However, should a spore fall on to suitable moist ground, it will germinate and branched threads will develop, as shown in figure 20.6.

Buds develop on the moss threads and these buds in turn sprout and mature into new gamete plants. This is asexual reproduction.

As spores fall on to the soil, germinate, develop threads and bud, a mat-like mass of moss plants develops. The plants clump together and thus trap a considerable amount of water. This helps to prevent drying out.

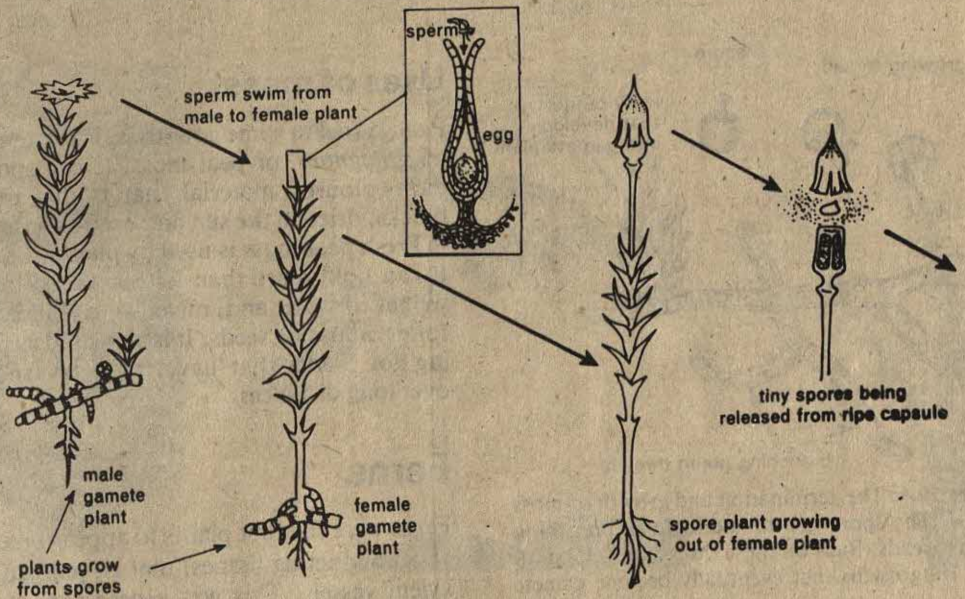

sperm
sperm swim from male to female plant
egg
tiny spores being released from ripe capsule
male gamete plant
female gamete plant
spore plant growing out of female plant
plants grow from spores

Figure 20.4: Life cycle of a typical moss.

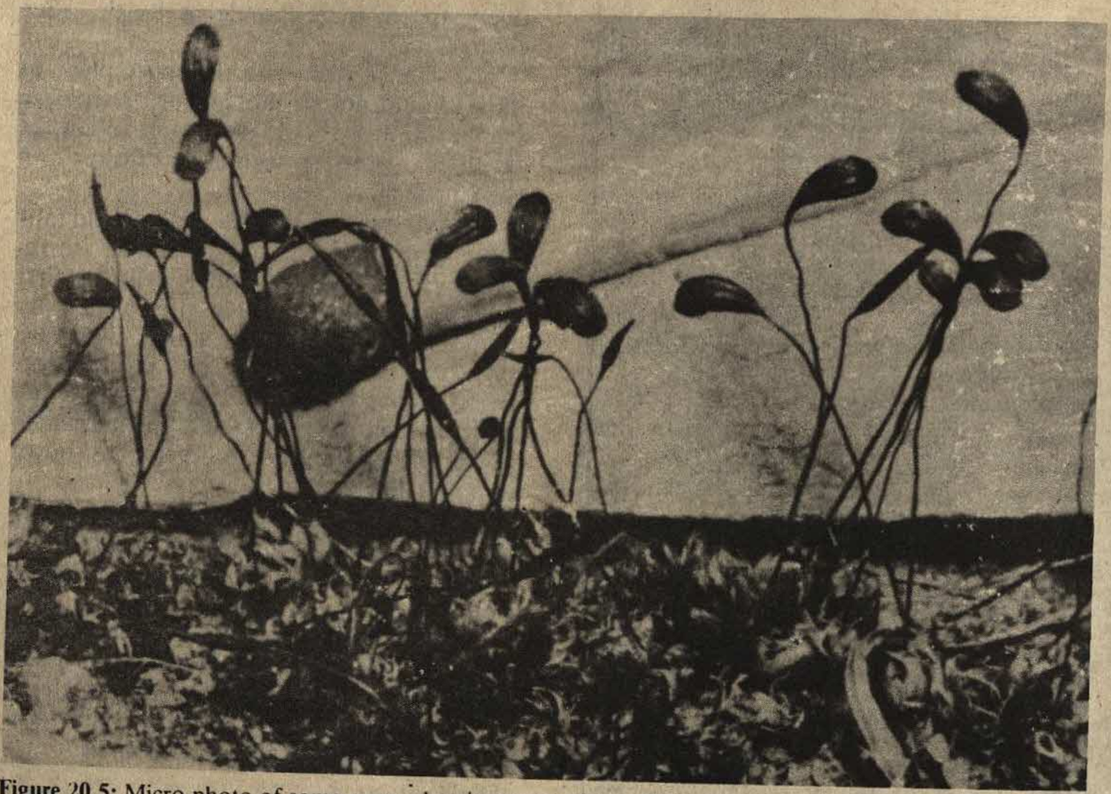


Figure 20.5: Micro-photo of some moss, showing spore plants. The safety match in the background gives an idea of the size of the plants.

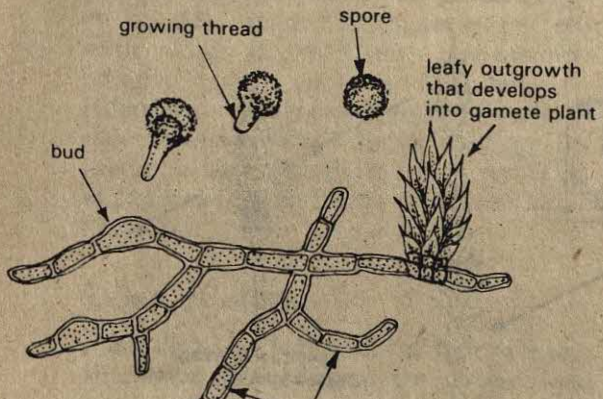


Figure 20.6: The germination and growth of moss spores. The spores germinate to form branching green threads. Buds on these threads develop into leafy outgrowths that eventually become gamete plants.

Uses of moss

Peat, a fuel in some countries, is the remains of *sphagnum*, or peat moss. It is a spongy, dark-coloured material that is dug out in blocks, dried in the sun and used as a fuel.

Fresh peat moss is used by plant nurseries. It can hold more than fifteen times its own weight of water and, mixed with soil, is used for germinating seeds. It is also used as packing for plants that have to be transported over long distances.

Ferns

Ferns were the first plants to appear on earth with conducting tissues, that is, phloem and xylem vessels. This was a necessary step if plants were ever to stand singly rather than in clumps. Figure 20.7 shows conducting vessels in leaves of maidenhair fern.

Every fern has a stem that bears roots and leaves. Part of the stem is usually underground. (See figure 20.8.)

Ferns usually grow in moist shady places. Tree ferns, the largest of the group, flourish in tropical and temperate rain forests. (See figure 20.9.) Duckweed is a fern that grows entirely in water. A fern that grows in drier places is bracken, which can be found on exposed hillsides that may become very dry during summer months.

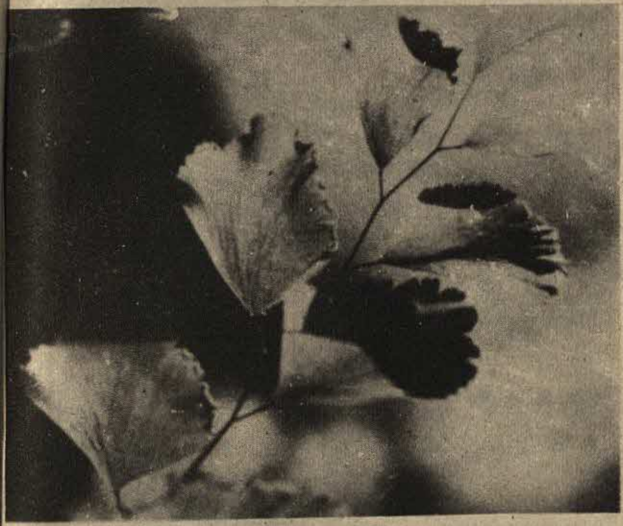


Figure 20.7: Some maidenhair fern leaves. Notice the veins: something not present in the foliage of moss plants.

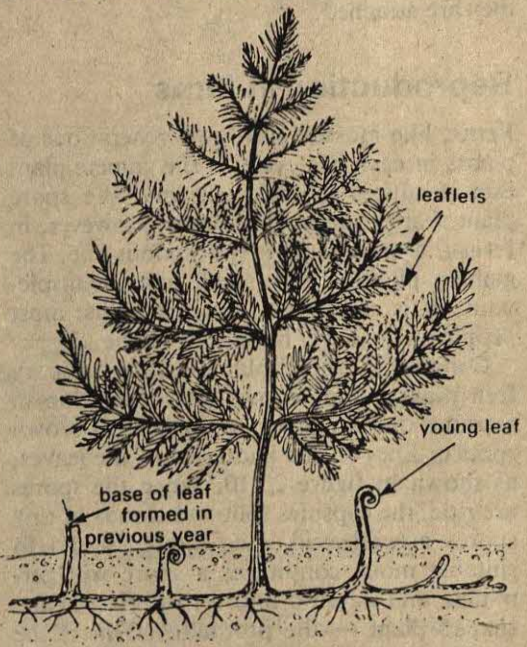


Figure 20.8: Bracken fern showing underground stem and roots.

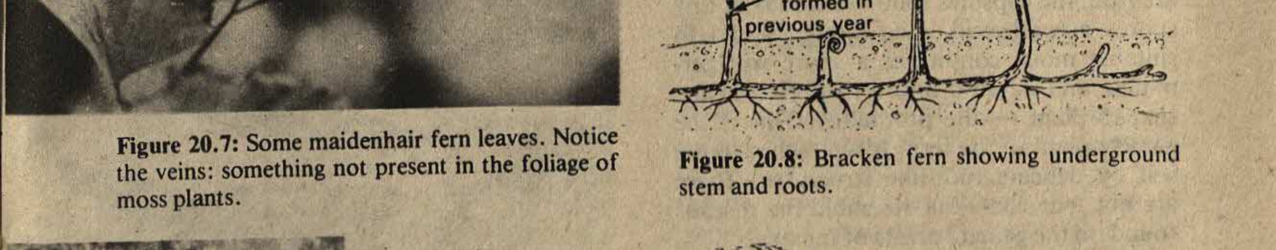


Figure 20.9: Some common ferns. A — tree fern. B — bracken fern. C — fishbone fern.

Some ferns, like the staghorn, grow high upon the trunks of trees. Such ferns have very short stems. They are not parasites, as they make their own food and absorb water that runs down the trunk of the tree to which they are attached.

Reproduction in ferns

Ferns, like mosses, have two generations of plants in each life cycle — the gamete plant that produces the sex cells and the spore plant that produces the spores. However, in ferns the spore plant is the obvious one. The gamete plant is very small and inconspicuous. It is called the fern prothallus; most people would never have noticed one.

Consider a spore plant — the ordinary fern plant we all know. Spores develop in capsules that are grouped together as brown spots or lines on the underside of the leaves, as shown in figure 20.10. When the spores are ripe, the capsules split and clouds of tiny spores are released. (See figure 20.11.) In suitable moist conditions a spore will germinate and develop into a tiny, flat, heart-shaped plant — the prothallus. This is the gamete plant of the fern. It is attached to the soil by delicate root-like structures. These are not true roots but resemble the threads found on the gamete plants of mosses.

The underside of the tiny prothallus contains both male and female sex organs. It is necessary for water to be present for fertilization to take place. Water is necessary because the sperm has to swim to reach the egg. (See figure 20.11.)

After fertilization the leafy fern plant grows and the prothallus withers and dies. The leafy fern plant corresponds to the stalked capsule of the moss plant and the prothallus to its leafy part.

The spore plant is successful mainly because it has water-conducting vessels. These and strong supporting tissues allow some varieties of ferns to grow large, for example, the tree fern. Ferns were the first plants to have roots, as well as the first to have conducting tissues. These enable them to establish themselves firmly in the ground.

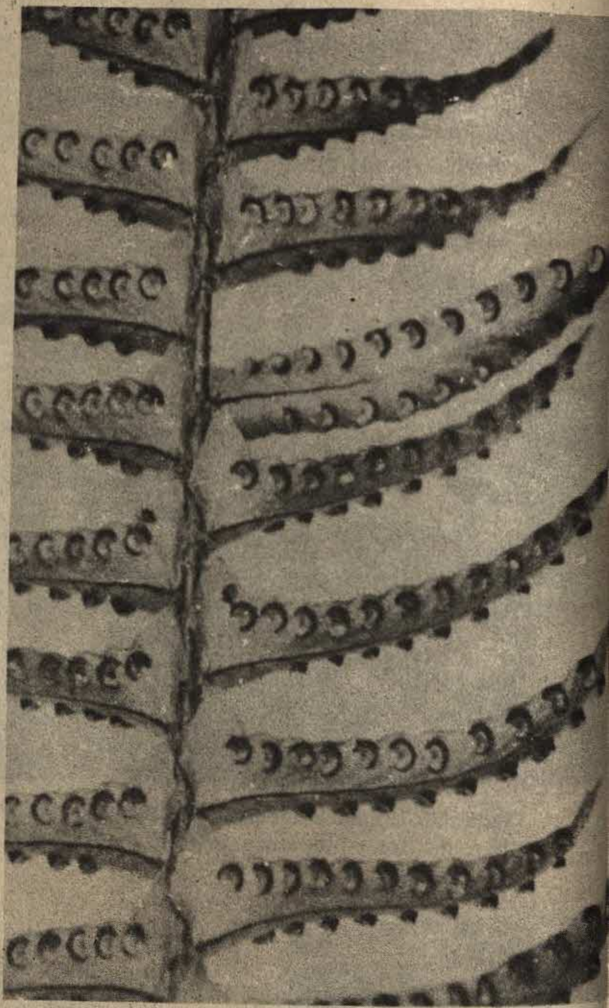


Figure 20.10: Sori underneath a fern frond. Each sorus is a capsule containing many fern spores.

The conifers

After the appearance of ferns, with their conducting tissues, the next big step in the evolution of the plant was the development of the seed.

Ferns and mosses are distributed by means of spores. A spore is very small; it is a single cell with practically no reserve of food. Therefore its chances of growing into a plant are very small.

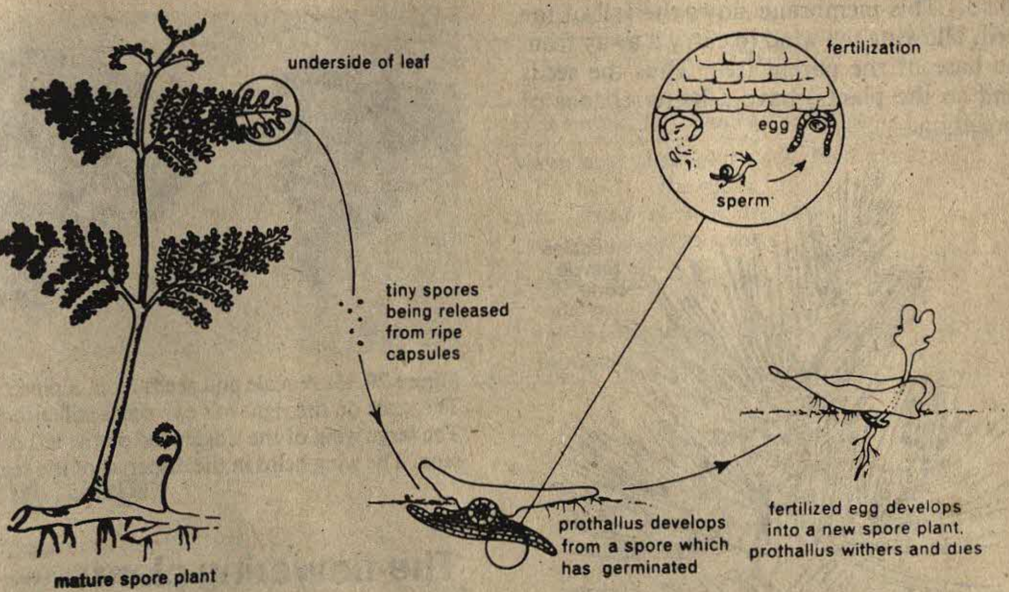

underside of leaf
tiny spores being released from ripe capsules
fertilization
egg
sperm
prothallus develops from a spore which has germinated
fertilized egg develops into a new spore plant, prothallus withers and dies
mature spore plant

Figure 20.11: Life cycle of a typical fern.

Seeds, on the other hand, contain a considerable reserve of food. They also contain an embryo plant, and are much larger than spores. Seeds give the next generation of plants a much better start in life than do spores.

Conifers were among the first seed-bearing plants to appear. They are sometimes called *gymnosperms*, which means "naked seeds". In contrast, the flowering plants bear seeds protected by fruit.

Conifers are found mainly in the temperate zones of the world. Many species are of great importance as a source of timber. Examples of conifers are pines, spruce, cedar, cypress and Douglas fir. Very few conifers are native to Australia. An exception is the indigenous cypress pine, which grows in the drier areas of the continent. It yields an attractive timber that is resistant to white ants and borers.

One of the most successful of the conifer species imported to Australia is the radiata pine. This was first introduced about 1870. It has been so successful that large tracts of land have been planted with it, to form the basis of our softwood industry.

Reproduction in conifers

Conifers, as the name implies, bear cones. There are two types of cones — male and female. (See figure 20.12.) Pollen grains are formed in the male cones, ovules in the female cones. Ovules contain the female gamete and structures that later form the seed. Female cones are generally much larger than male cones.

During spring, the central stalk of the green female cones grows longer. This causes the scales bearing the ovules to become slightly separated. At the same time, pollen is shed from the male cones and drifts in between the scales of the female cones. The sperm cells from the pollen grains fertilize the egg cells in the ovules. The fertilized cone then grows to three or four times its size when green. During this period, which may last for as long as a year, the covering of each ovule hardens and becomes a seed coat. The scales of the cone become brown and woody.

In dry weather the cones open again and release the seeds. To each seed is attached a thin membrane like a wing. (See figure

20.13.) This membrane slows the fall of the seed, allowing the wind to carry it away from the base of the parent tree. Thus the seeds (and so the plants) have a better chance of spreading.

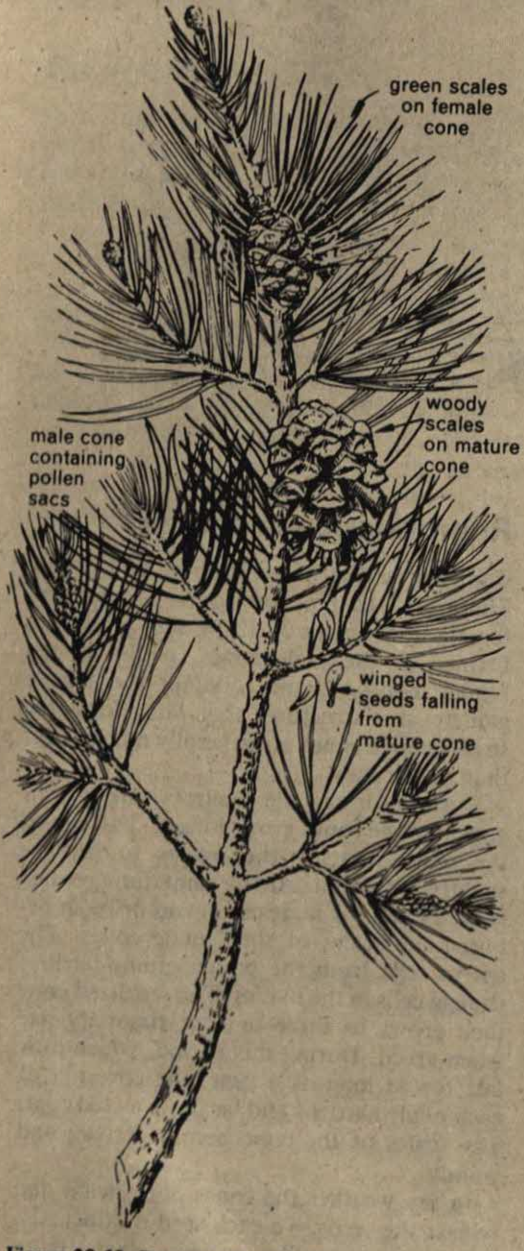

green scales on female cone
woody scales on mature cone
male cone containing pollen sacs
winged seeds falling from mature cone

Figure 20.12: Branch of a typical pine in spring.

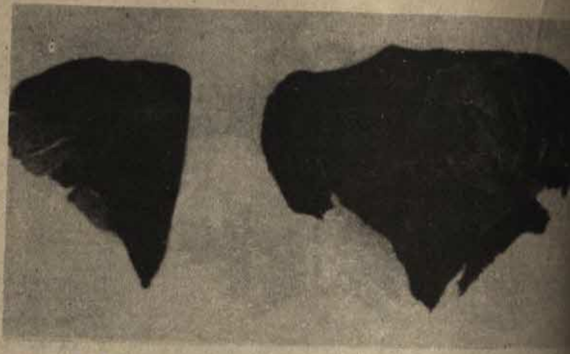


Figure 20.13: A scale and seeds from a pine cone. The scale on the right has two seeds still attached. The large wing of the single seed on the left can be seen. The wing helps in the dispersal of the seed.

The flowering plants — the angiosperms

The angiosperms, the most recent group of plants to appear, are the most successful of the land plants. They have some of the adaptations of the gymnosperms — strong tissues in the stem and efficient conducting tissues to take nutrients throughout the plant. Like gymnosperms, they have no need of water to transport male gametes to the female gamete for fertilization.

However, angiosperms have some adaptations that have made them far more successful than the gymnosperms. Many angiosperms, for example, are pollinated by insects. This is a far more efficient method than wind pollination. Furthermore, the seeds of angiosperms lie within a fruit. This offers protection for the seeds and also leads to other methods of dispersing the seeds. For example, animals eating the fruit carry the seeds in their bodies before passing them out, usually at some distance from the parent plant. Some seeds have hooks on them that cling to the fur of animals; as the animals move about the seeds are dispersed.

Angiosperms were treated in greater detail in chapters 11 and 13.

Table 20.1 sets out a brief history of plants on earth.

Table 20.1: History of plants on earth

Era	Number of million years ago	Events
Precambrian Era	approx. 1000	First simple algae appear in the sea.
Palaeozoic Era	400	Many large algae in the sea. First plants on dry land — the mosses.
	350	First ferns appear on dry land.
	300	First gymnosperms evolve.
Mesozoic Era	150	Gymnosperms abundant. First angiosperms appear.
	100	Angiosperms abundant. Gymnosperms diminish in number.

The fungi

Fungi are different from the various groups of plants already treated in this chapter. Fungi do not have chlorophyll: they get their food by feeding on other organisms. If they feed on dead organic material they are called saprophytes; if they feed on living organisms, they are called parasites.

Fungi include toadstools, mushrooms, moulds, mildews and yeasts. Unlike ordinary plants, they don't have true roots, stems or leaves and don't make their own food. Instead they absorb their food through threads buried in the material on which they are growing. The mould on bread is an example. (See figure 20.14.) The threads in the bread secrete enzymes. These enzymes change the bread into a form that can be absorbed through the threads.

The structure of a mould

The plant body of a mould is the thin threads that spread over and through the material on which it is living. Some of the threads grow upwards and bear round white bodies that soon turn black. These are the spore cases. When the spores in them are ripe, the cases break open and release thousands of spores into the air.

The spores are very light and may be carried considerable distances by the slightest breeze. Ordinary house dust usually contains many spores carried in by the wind.

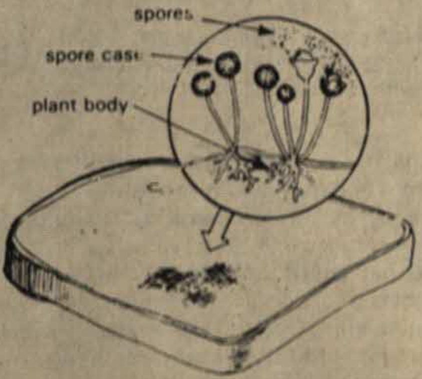


Figure 20.14: Mould growing in bread.

Each spore is enclosed in a casing that protects it and enables it to live for long periods, even under unsuitable conditions. A spore cannot germinate and grow unless it falls on suitable food and has favourable conditions for growth. Experiment 20.7 investigates these conditions.

Mushrooms and toadstools

The common mushroom is another type of fungus. The cap is the reproductive organ of the plant. The stalk and cap of the mushroom (see figure 20.15) are made up of closely packed threads. In young mush-

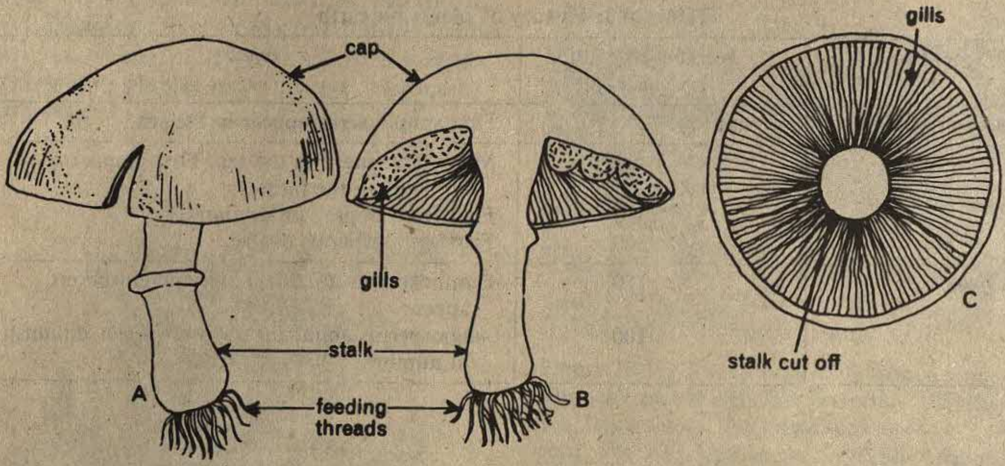


Figure 20.15: A — mushroom. B — mushroom cut lengthways. C — underneath of cap of mushroom.
Note feeding threads by means of which this fungus obtains its food. The spores are formed on the gills of the mushroom.

rooms the cap is cream coloured; later it darkens and may even turn brown.

As the mushroom matures the cap opens out to expose the gills. At first these are pink, but later they turn dark brown. Vast numbers of spores are produced on the sides of these gills. Question 20.16 suggests making a spore print from a mushroom cap.

Mushroom spores may germinate if they fall on suitable ground. The spores send out threads that form the plant bodies of new mushrooms. Mushroom-growers call the mass of branching threads "mushroom spawn".

Fungi — both useful and harmful

The table mushroom is a delicacy to many people. The mushrooms sold in shops are grown under controlled conditions, but if you have access to farm land you can still go gathering them after light rain. However, as you may have heard, people have been poisoned and even died from eating what they thought were edible mushrooms. There is no easy way to identify the edible variety and you should not eat any fungus unless you are quite sure it is non-poisonous.

A very useful fungus is the common blue-green mould *Penicillium*, from which penicillin is extracted. Penicillin is given to people and other mammals infected by harmful bacterial diseases. It destroys the bacteria and for this reason is called an "anti-biotic".

Other types of fungi are important in cheese-making. For example, blue-vein cheese is coloured by a fungus that gives the cheese its characteristic flavour.

Yeast is a fungus used in making beer and wine. It is also used in bread-making — the carbon dioxide it produces causes the dough to rise.

On the other hand, there are many harmful fungi. The rust that can cause serious damage in wheat crops is a fungus. So is the potato blight that was responsible for the devastating famines in Ireland. Many common vegetable crops, such as tomatoes, can also be affected by fungi. Tinea and ringworm are fungus diseases of the human body. All these fungi are parasites: they feed on another living organism.

Lichens

You have probably noticed some brightly coloured encrustations on tree trunks, bare rocks and on burnt ground. These are lichens.

Lichens are really two organisms in one. They consist of a fungus and an alga living together. The fungal threads absorb moisture from the air and release acids that attack the rock or soil. In this way mineral salts are produced. The algae are thus provided with water and natural salts. From these and the carbon dioxide in the air the algae make organic substances. The fungi feed on these organic substances. Both the organisms in a lichen thus depend on each other. This is an example of symbiosis.

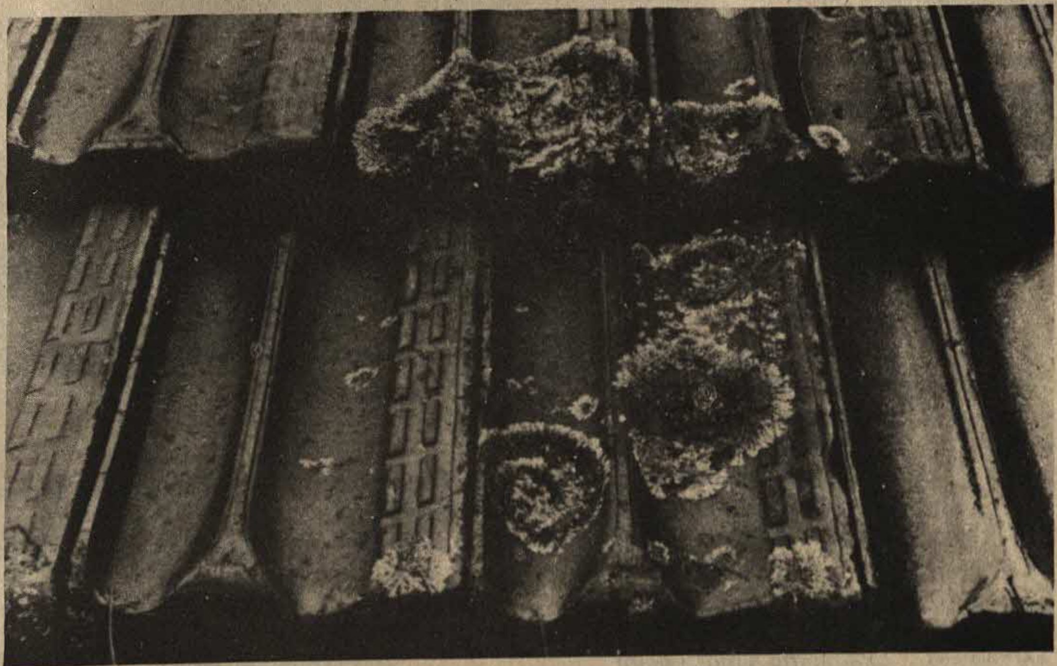


Figure 20.16: Lichen on roof tiles. Lichen consists of an alga and a fungus living together and depending on each other.

EXPERIMENT

20.1

Examining algae with a microscope

Each group will need:

- microscope
- microscope slide and cover slip
- sample of pond slime. (If possible, obtain some of the green thread-like slime. Store it in a jar of water until you're ready to use it.)

What to do

- Place a piece of algal filament in a drop of water on a microscope slide. Cover it with a cover slip.
- Examine the filament with the low-power lens of a microscope.

- Next, examine a portion of a thread with the high-power lens. It may help if you stain the specimen with iodine solution.

Questions

20.1 Did you find that the filament was a continuous thread — or was it made up of cells?

20.2 Could you identify a cell wall, vacuoles, chloroplasts or nuclei when using the high-power lens?

EXPERIMENT 20.2

Examining seaweed

Each group will need:

- sample of seaweed stored in a bucket of seawater
- saucepan
- tripod
- Bunsen burner
- hand lens

What to do

- If the seaweed is brown or red, boil it for a few minutes in fresh water.
- Examine the seaweed with a hand lens; look for veins.

Questions

20.3 Did the brown or red seaweed become green on boiling? What do you think the green colour could indicate?

20.4 Did you notice any veins in the seaweed? How does a seaweed get its water and nutrients?

EXPERIMENT 20.3

Examining a moss plant

Each group will need:

- clump of moss
- hand lens
- small knife
- microscope
- slide and cover slip

What to do

- Examine the moss with the hand lens. Look for a spore capsule on a stalk.
- Squeeze the capsule, if you've found one.
- Try to detach a single moss plant and measure its length.
- Scrape a piece off a moss leaf. Examine it under the microscope, using first the low-power and then the high-power lens.

Questions

20.5 Were you able to see a spore capsule? Was it possible to split it?

20.6 What was the length of the moss plant you measured?

20.7 Were you able to identify single cells in the moss leaf?

20.8 Did the cells appear to have the usual structures found in a plant cell?

EXPERIMENT

20.4

Examining bracken fern

Each group will need:

- a clump of bracken fern as it was growing, with some underground stems and roots
- hand lens

What to do

- Examine the leaves of the fern. Look for groups of spore capsules. (Early summer is the best season for this examination.)
- Examine a leaf with the hand lens. Look for veins.
- Examine an underground stem. Look for buds indicating new fern fronds.

EXPERIMENT

20.5

Examining the leaves of different species of conifers

Each group will need:

- small branches of various conifers

What to do

- Examine the leaves of the various species. Note that they are needle-shaped, and that some are in clusters and some are segmented.

Question

20.9 Draw three different kinds of conifer leaves, noting the name of the conifer each kind came from.

EXPERIMENT

20.6

Examining pine cones

Each group will need:

- samples of green male and female cones
- samples of mature, woody female cones
- sharp knife or small saw

What to do

- Go to a conifer and collect one or two male and female cones.
- Lay the cones out on the bench with labels indicating the species of tree each came from.
- Cut open several cones to examine their structures. Examine the scales of the female cones, looking for ovules at the base of each scale.
- Break off scales from the old, woody female cones, looking for winged seeds.

Question

20.10 Whereabouts on the tree did you find the cones? Are the female and male cones found in the same positions?

EXPERIMENT 20.7

Under what conditions does mould grow on bread?

Each group will need:

- piece of stale bread
- four test tubes
- four stoppers

What to do

- Leave the piece of bread in the open near a window for a day in order to collect spores.
- Cut the bread into four small pieces.
- Place a piece of dry bread in one test tube, pieces of damp bread in the next two, and a piece of soggy bread in the fourth.
- Stopper each test tube.
- Place one of the test tubes containing damp bread in a refrigerator.
- Place all the other test tubes in a warm position.
- When mould appears on one sample of bread (it will take several days), examine the other samples closely.

Questions

20.11 What conditions appear most favourable for the growth of mould?
20.12 How would you store bread at home to prevent it going mouldy?

Spelling list

alga
algae
angiosperm
asexual
bracken
capsule
conifer
cypress
embryo
fertilize
fungus
gamete
gymnosperm
lichen
mould
parasite
peat
penicillin
prothallus
saprophyte
sperm
spongy
spore
stalk
tinea
zygote

Things to do

20.13 Next time you visit an ocean beach, look for various samples of seaweed. Note the shape of the "leaves" and any holdfasts that may be present. As well, look in rock pools for green, brown and red seaweeds. Look for sex organs on *Hormosira*, if there is any present.

20.14 On your next bush walk, note the particular habitats of ferns. Look for tree ferns and staghorns. Look out also for burrawang palms. These are a cone-bearing plant, in which the female cone grows up to 40 cm in length.

20.15 Germinate some fern spores in a flower pot. Place 3 or 4 cm of gravel in a 15 cm clay flower pot. Cover the gravel with about 8 cm of potting soil. Place some pieces of broken clay pot on the soil. Water until damp. Scatter spores from a bracken leaf into the pot. Cover the pot with a sheet of glass and stand it in about 6 cm of water. The pot should be left in a shady spot outside, protected from draughts. It takes 4–8 weeks for fern prothalli to appear.

20.16 Make a spore print from a mushroom cap. Remove the stalk from a fresh open mushroom. Lay the cap with the gill side down on a sheet of white paper. Cover the cap with a glass jar. Leave for 24 hours.

20.17 Germinate mould spores on potato. Cut slices of potato and dip them for a minute in boiling water to which a little vinegar has been added. When the potato is cold, dust some spores from mouldy bread on to its surface. Cover the potato with a glass jar to prevent drying out. Examine the resultant mould with a binocular microscope.

20.18 Shake some ripe male cones (from any convenient conifer) over a microscope slide. Examine the pollen with a microscope, noting the pair of air bladders that is part of the structure of each grain.

Plants

Algae	Mosses	Ferns	Gymnosperms	Angiosperms	Fungi
simple water plants — no stems or leaves	small green plants that grow in tufts — have stems and leaves	green plants containing fronds — well-developed root system	cone-bearing plants with uncovered seeds — needle-shaped leaves — usually evergreen	flowering plants with seeds enclosed in a fruit — both evergreen and deciduous	multicellular organisms with feeding threads
all contain chlorophyll and make their own food by photosynthesis (they are autotrophic)					do not make their own food — live on dead or living material
nutrients absorbed from one cell to the next		nutrients carried through conducting vessels and also absorbed from cell to cell			nutrients absorbed from one cell to the next
reproduce by cell division or from spores	two plants in each life cycle — the spore plant and the gamete plant		reproduce mainly from seeds		from spores

More questions

20.19 The first plants on earth were the algae. What parts of the earth did they colonize? Have they moved from these habitats? Give a reason for your answer.
20.20 Why are moss plants usually very small?
20.21 How does the clumping habit of mosses help them to survive?
20.22 Explain why mosses reproduce only under moist conditions.
20.23 What adaptation has enabled some ferns to grow very large?
20.24 What is the function of the fern prothallus?
20.25 In both mosses and ferns there are two generations in each growth cycle. Name these generations. Which is the more obvious generation in (a) mosses, (b) ferns?
20.26 What are spores? In what way do they differ from seeds? List some of the advantages that seeds have over spores.
20.27 How do the seeds of gymnosperms differ from those of angiosperms?
20.28 Explain the statement "Fungi are heterotrophic".
20.29 What are lichens?

Test yourself (chapter 20)

Write the answers in your workbook.

1. Name the simplest class of green plants.
2. Which is the more primitive structure — seed or spore?
3. What is the name given to the sex cells of plants?
4. Which class of plants do not produce chlorophyll?
5. What is the name given to an organism that feeds on another living organism?
6. What is the scientific name for cone-bearing plants?
7. What is the scientific name for flowering plants?

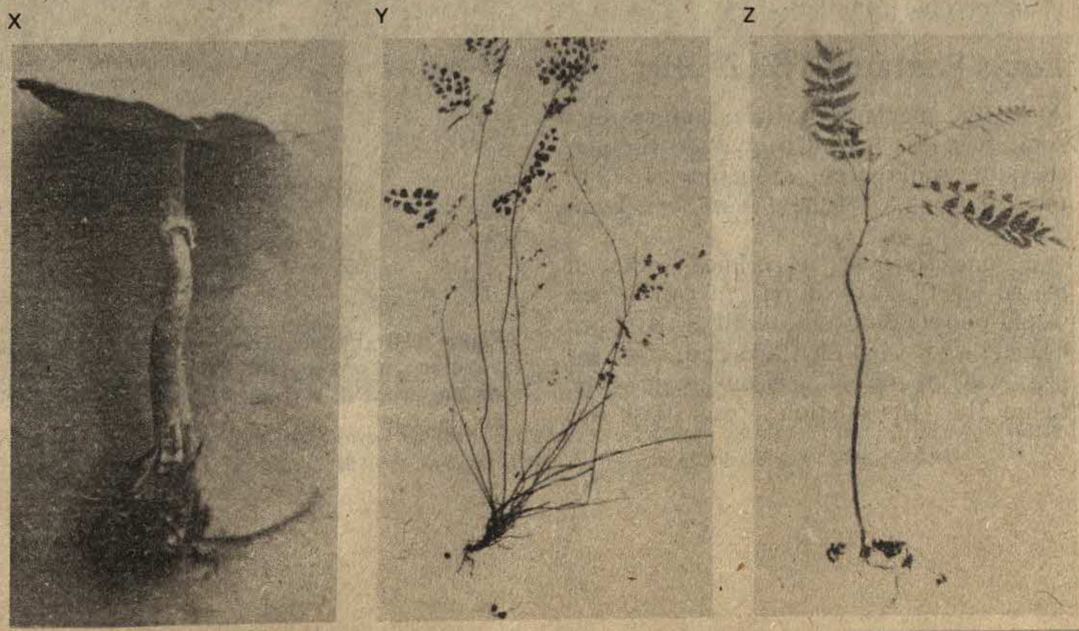
In each of the following questions, choose the best answer and write its letter in your workbook.

8. Which of the following classes of plants provide the most food for humans?
   (a) flowering plants
   (b) algae
   (c) fungi
   (d) conifers.
9. Which group of plants all have leaves with veins?
   (a) bracken, moss, spruce
   (b) cedar, wattle, bracken
   (c) algae, pine, mushroom
   (d) pine, moss, staghorn.
10. The function of a gamete plant is to produce a
   (a) sex cell
   (b) seed
   (c) spore
   (d) zygote.

11. Which of the following is *not* a fungus?
    (a) staghorn
    (b) tinea
    (c) mushroom
    (d) mould.
12. Which pair of plants has both gamete- and spore-producing parts?
    (a) fern and flowering plant
    (b) moss and conifer
    (c) moss and fern
    (d) conifer and flowering plant.
13. In which plant is water necessary for the fertilization of the female gamete?
    (a) water-lily
    (b) bracken fern
    (c) Norfolk pine
    (d) water hyacinth.
14. Of the following, the two plants most closely related are
    (a) seaweed and moss
    (b) moss and water-lily
    (c) cypress pine and seaweed
    (d) bracken fern and wattle.
15. In the photographs below, the organisms X, Y and Z are examples of which groups of plants? Choose from (a), (b), (c) and (d) below.

	X	Y	Z
(a)	fungus	flowering plant	fern
(b)	fungus	fern	flowering plant
(c)	flowering plant	fungus	moss
(d)	moss	flowering plant	fungus

Figure 20.17



21

Micro-organisms: bacteria and viruses

Even just two hundred years ago, the stench of a city like London would have been intolerable by today's standards. Sewers were often open to the air, urine was flung out into the street and garbage disposal was inadequate. People were surrounded by decay. They had little knowledge of how to preserve food and did not know why it "went bad". They were likely to be struck down at any time by a disease that they did not understand and were powerless to check.

It was known, of course, that stale bread became mouldy and that meat kept more than a few days would putrefy. But even scientists thought that these changes were spontaneous, that is, occurred within the food itself without any outside cause. People even believed that the appearance of maggots in meat was due to a chemical change within the meat itself. They had no idea that maggots come from flies.

Louis Pasteur (1822–95)

About the middle of the nineteenth century, some scientists began to question the idea that life could begin spontaneously. The most outstanding of these people was Louis Pasteur.

In one series of experiments Pasteur placed in flasks solutions that he knew would putrefy on contact with air. He then heated the necks of the flasks and, when the glass was soft, drew them out as shown in figure 21.1. The solution in each flask was then boiled until steam issued from the tube for several minutes. This killed any living things in the solution and the tube. When the flask was allowed to cool, steam condensed in the bend of the tube, as shown. This water trapped any bacteria entering from the air. As long as this seal remained, the solution did not putrefy.

However, if the flask was tipped up, so that the solution mixed with the water in the neck, putrefaction commenced after a few days. Pasteur's conclusion was that putrefaction was caused by living organisms entering the solution from the air.

Pasteur had great difficulty in getting his conclusion accepted. He had to do many experiments and present many papers before people would believe that putrefaction did not start spontaneously.

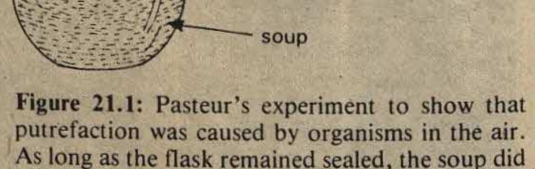


Figure 21.1: Pasteur's experiment to show that putrefaction was caused by organisms in the air. As long as the flask remained sealed, the soup did not "go bad".

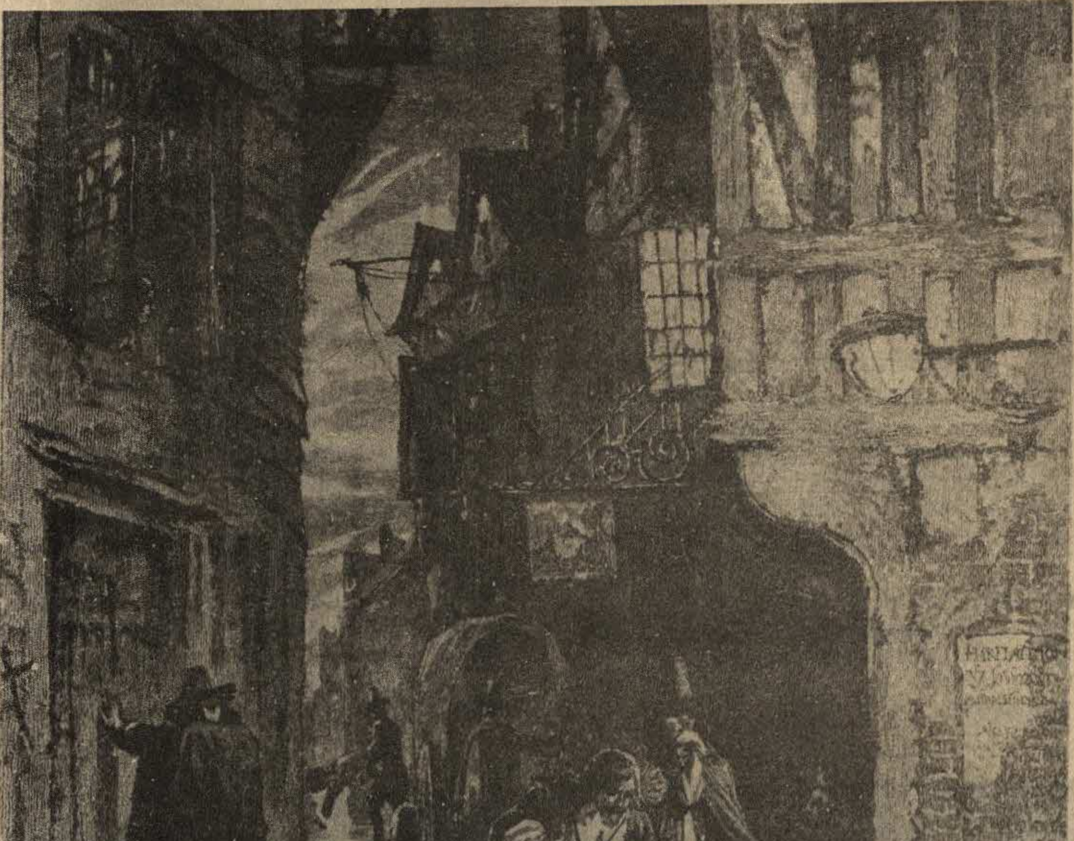


Figure 21.2: This old engraving shows a scene in a London street during the Great Plague, 1665–66. Notice that the street is unpaved and that there is an open gutter. What causes the disease called plague?

Bacteria

The commonest agents of putrefaction are bacteria. These are single-celled organisms with cytoplasm, nucleus and a rigid cell wall.

Figure 21.3 is a drawing of a bacterium and figure 21.4 is a micro-photograph of a thin slice of material containing bacteria.

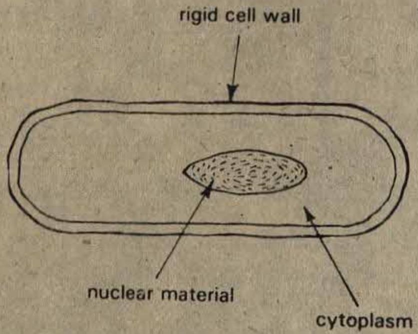


Figure 21.3: A typical bacterium. The cell wall is composed chiefly of protein. This is unlike a plant cell, in which the wall is composed of cellulose. Some bacteria have flagella; others have chlorophyll.

The photo shows two new bacteria that have just been formed by the division of a single cell. The variety of bacterial shapes shown in the photo is caused by the variety of angles at which the bacteria were lying when the slice of material was cut off.

Bacteria are very small, ranging from 0.0001 to 0.0003 cm in length. They are of various shapes — rods, spirals and spheres. (See figure 21.5.) Some have flagella (see figure 21.5C) that allow them to move. Bacteria like these might be classed as animals. Other kinds of bacteria contain chlorophyll, which puts them in the same family as plants.

Not all bacteria are harmful; many kinds play an important part in living processes. For example, the soil is teeming with bacteria; without them most plants and animals would eventually become extinct. Think of the numbers of trees and animals that have lived and died in the tropical forests of the world alone in the last 100 million years. What has happened to their bodies, which were once lying on the forest

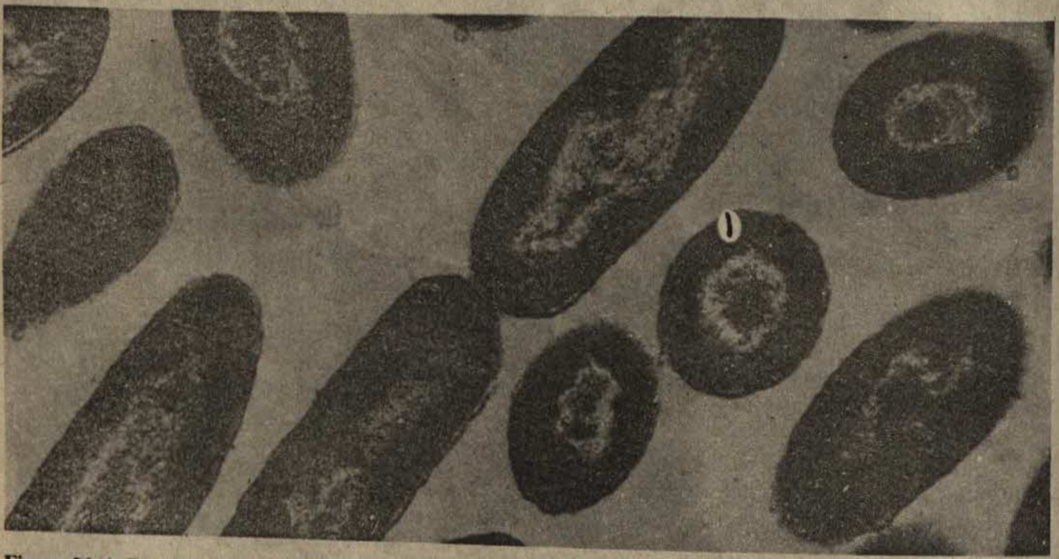
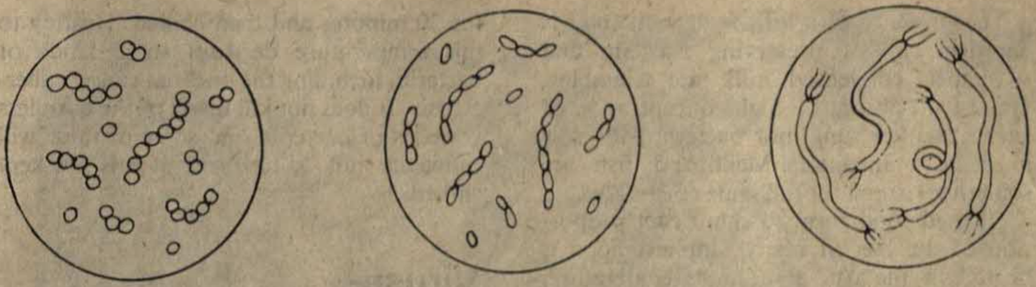


Figure 21.4: Bacteria of the bacillus group magnified 20 000 times by an electron microscope. To take this photograph, the bacteria were first fixed in plastic. A very thin slice was then cut from the plastic and placed in the microscope. Can you explain the complete wall in some of the bacteria and the fuzzy edges on the others? (Photo courtesy Dr M. R. Dickson, University of New South Wales)



(a) Cocci (b) Bacilli (c) Spirilla

Figure 21.5: The three classes of bacteria.

floor? They have been decomposed by fungi and bacteria into simple substances that have been returned to the soil and air. In this way the fertility of the soil has been maintained and the level of carbon dioxide in the atmosphere kept constant.

Another, more particular, example of the usefulness of bacteria can be found in the intestines of the koala. The koala needs special bacteria to help digest the eucalypt leaves that are its special diet. Without these bacteria it would die. Without the koala the bacteria could not exist. This type of relationship, where two different organisms need each other in order to live, is called symbiosis.

Most people enjoy yoghurt. How many people know that yoghurt is formed by the action of a certain kind of bacteria on milk?

Experiments 21.1, 21.2 and 21.3 are further investigations of bacteria.

Bacterial diseases

Bacteria are responsible for a number of common diseases. Some of these are pneumonia, meningitis, tonsillitis, boils, typhoid, tetanus and syphilis. In most cases the harmful effects of the disease are not due to the bacteria themselves but to the poisons, or toxins, they produce as they feed on the body tissues.

However, the body is not completely defenceless against these bacteria. Their presence stimulates it to produce antibodies. These substances help to kill the disease-causing bacteria and to destroy the poisons they produce. In some diseases, if the affected person recovers, enough antibodies remain in the blood to render him immune to future attacks by the same bacteria. This explains why, if we suffer from some diseases once, we are not likely to contract them again.

Immunization against diseases

Immunity to a number of diseases can be given by the injection of a vaccine. A vaccine is a weakened culture of the disease. When injected into a person it produces a mild attack that stimulates the body to produce antibodies. After the mild attack subsides, the antibodies remain and give the person immunity against possible future infection by the same disease.

Protection of food against bacterial action

Damp conditions favour the growth of moulds and bacteria. If food is kept dry, these organisms cannot spoil it. You probably know how soon fresh vegetables begin to "sweat" and rot and, in comparison, how long dried peas will keep if stored in a screw-top jar.

Refrigeration is another way of preserving food. Deep-frozen meat and vegetables will keep for months. Though few bacteria are killed by freezing, bacterial growth is either prevented or greatly retarded.

The presence of a lot of sugar in food is another way of preserving it. Jam and sweetened condensed milk are examples. Dried fruit also has a high concentration of sugar. Neither fungi nor bacteria will grow in such a medium. Meat and fish are sometimes salted for the same reason.

Canned food forms a significant proportion of the diet of many families. Food is heated in the can at a high temperature, under pressure. Heating in this way destroys all bacteria and fungi. As long as the can remains sealed the food in it will last indefinitely. Recently some food canned at the time of the Napoleonic Wars (1805–15) was opened for testing and found to be uncontaminated.

Milk is partially preserved by pasteurization. In this process the milk is kept at 65°C for 30 minutes and then chilled. Heating to this temperature destroys some kinds of bacteria, including the one that causes tuberculosis. It does not kill many of the harmless varieties of bacteria, and some of these will cause the milk to turn sour if it is not kept chilled.

Viruses

Viruses cause diseases of animals, plants and bacteria. (See figure 21.7.) Some of the better-known virus diseases of people are influenza, poliomyelitis, measles, mumps and the common cold. There are many virus diseases of plants. These cause crop losses valued at millions of dollars annually.

Viruses were discovered only in recent

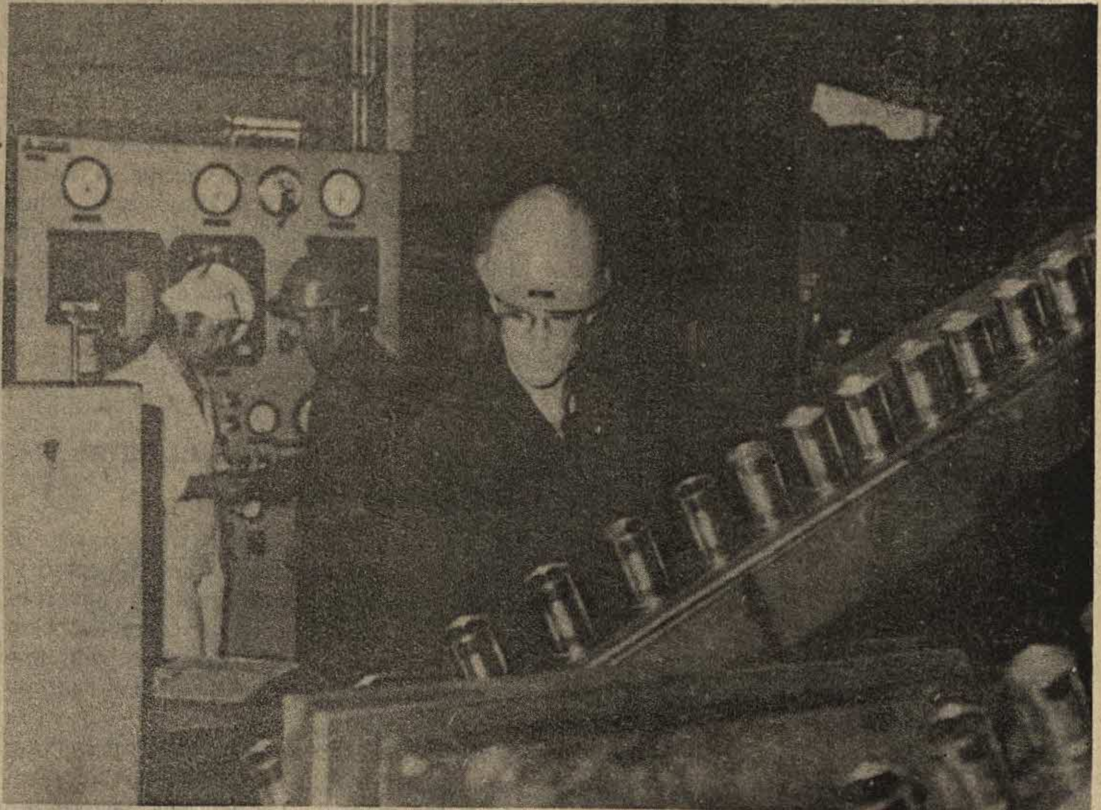


Figure 21.6: Canned food being sterilized by heating in large pressure cookers in the Heinz factory in Victoria. (Photo courtesy H. J. Heinz Company Australia Ltd)

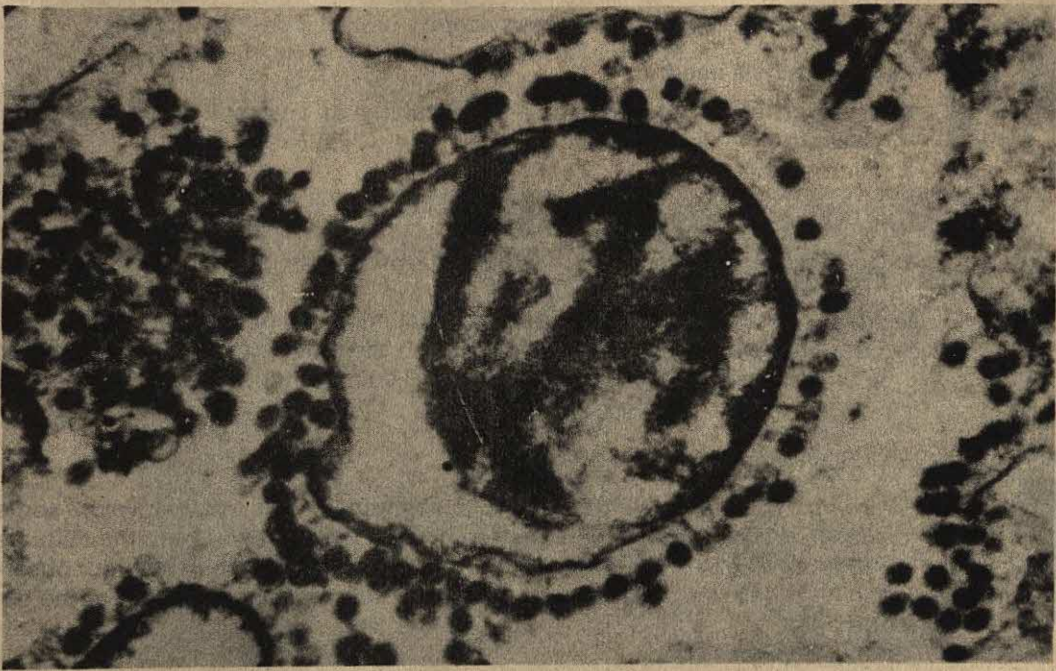


Figure 21.7: A bacterium being attacked by virus. The viruses are the small dark objects surrounding the bacterium. This gives some idea of how the cells of the body may be attacked by a virus infection. This photograph was taken by an electron microscope and is magnified about 45 000 times. (Photo courtesy Dr K. Y. Cho, John Curtin School of Medical Research, Australian National University).

years. They are extremely small, much smaller than the smallest bacteria; they pass through the finest filters.

Viruses are the most elemental form of life we know. They seem to occupy an intermediate position between living and non-living matter. The virus particles are like tiny crystals; they do not have the usual cell structure of living organisms.

Each virus has a characteristic shape and size. For example, the poliomyelitis virus is spherical.

Viruses can reproduce only in living cells and each virus infects only one particular host. For example, poliomyelitis virus infects only nerve cells. The particles reproduce in the cells, and, in doing so, destroy the cells. For this reason poliomyelitis can cause paralysis.

Plants and animals are continuously in contact with viruses and bacteria of many kinds. However, these do not normally cause disease because plants and animals have a resistance to them. This resistance is inherited and has been built up over many generations.

What, then, causes an organism to become diseased? Here are three possible reasons:

- The organism comes in contact with a strange disease against which it has no resistance. Highland natives of New Guinea, for example, had no resistance to influenza introduced by white people from Australia.
- The organism comes to be surrounded by diseased organisms. We are more likely to catch a cold if we mix with a lot of people with colds.
- The organism's general health is not good. For example, people (and other animals) are more prone to disease if they do not have a balanced and adequate diet.

EXPERIMENT 21.1

Observing bacteria under the microscope

Each group will need:

- prepared slides of bacteria – particularly of common disease-causing bacteria
- microscope

What to do

- Look at each slide in turn, first with the low-power objective and then with the high-power objective.
- Identify each kind of bacteria as rod-shaped, spiral or round.
- Draw a few of the bacteria seen on each slide, noting particularly whether they are single-celled or in groups. Label each sketch.

EXPERIMENT 21.2

Where do bacteria come from?

Warning: It is possible that in this experiment you may develop some disease-causing bacteria. It is therefore important that you keep the cultures covered at all times and destroy them when you have completed your observations. Wash your hands thoroughly with soap at the conclusion of the experiment.

Each group will need:

- six sterilized petri dishes with covers
- small flask of nutrient jelly (see appendix 1 for details of preparation)
- loop of nichrome wire
- felt pen
- samples of milk and damp soil

What to do

- Melt the jelly by placing the flask in boiling water.
- Half-fill six petri dishes with melted jelly (see figure 21.8). Do not breathe into the dishes, and cover them immediately. Number each dish with a felt pen.
- Expose one lot of jelly to the air in the room for twenty minutes and re-cover it.
- Rub a finger across the second dish and re-cover it.
- Touch the third dish with your lips. Re-cover.
- Sterilize the loop of nichrome wire in the Bunsen flame, place it in some milk and draw the wire across some jelly in the fourth dish. Re-cover.
- Sterilize the wire again, dip it into some wet soil and streak the fifth dish with it. Re-cover.
- Do not open the sixth dish. Use it as a test to check that the jelly was free of bacteria when poured out of the flask.
- Place all the dishes in a warm place for two days (preferably an incubator set at 37°C).

Question

21.1 Describe the appearance of the jelly in each dish after two days. Were all the cultures the same colour?

- With the nichrome wire, remove some of the culture from one dish and place it on a microscope slide. Warm the slide gently above a Bunsen flame to fix the sample to the glass.
- Add a drop of iodine solution to the sample. After about two minutes, wash the slide in water, add a cover slip and examine under a microscope.

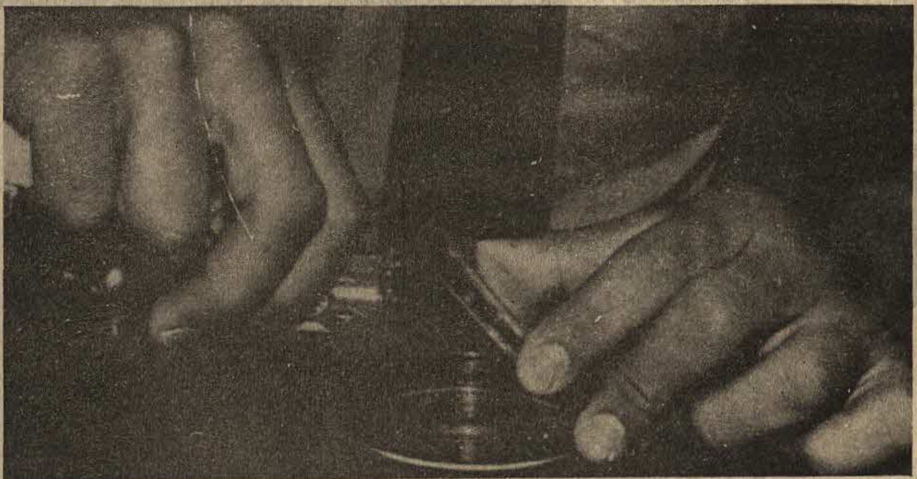


Figure 21.8: Showing how to add nutrient jelly to a sterilized petri dish.

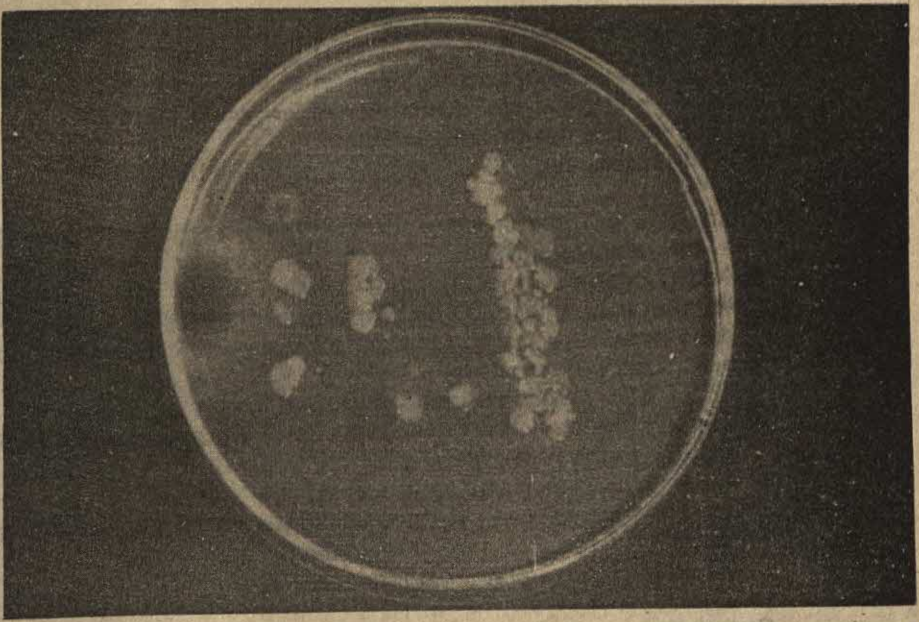


Figure 21.9: Bacterial cultures in jelly in a petri dish. The shapes on the right are the result of drawing the wire across the jelly. Any fungal colonies can usually be detected by the presence of threads. Notice the patch of fungus on the left.

Question

21.2 Were you able to see any bacteria? Draw a diagram to indicate their shape or shapes.

- At the conclusion of your experiment, place the dishes in 20% formalin solution overnight before cleaning. Wash your hands thoroughly.

EXPERIMENT 21.3

Preventing the growth of bacteria

Each group will need:

- six peppercorns
- 100 mL beaker
- mortar and pestle
- glass jar
- six petri dishes or aluminium bottle tops (unsterilized)
- nutrient jelly
- dropper
- household disinfectant
- soap
- detergent
- sugar
- penicillin tablet

What to do

- Crush the peppercorns in the mortar. Place the resulting powder in the beaker and cover with water. Leave for two or three days in a warm place to encourage the growth of bacteria.
- Melt the jelly and half-fill each dish (or bottle top) with it. Allow the jelly to solidify.
- Add two or three drops of the bacteria suspension to each dish. Spread evenly over the surface.
- Add two drops of disinfectant solution to one dish, two drops of soap solution to the second and two drops of detergent solution to the third. Use the same proportion of each substance in water as you would for normal household purposes.
- Add a 40% sugar solution to the fourth.
- Dissolve the penicillin tablet in a cup of water and add two drops of the solution to the fifth dish.
- Keep the sixth dish as a control.
- Label the dishes and set them aside in a warm place (under a glass jar if using bottle tops) for two or three days.
- Tabulate your results.

Questions

21.3 In which dishes did the bacteria continue to grow?

21.4 Which substances prevented the growth of bacteria?

Micro-organisms: bacteria and viruses

	Bacteria	Viruses
Description	single-celled organisms of various shapes; often occur in groups	very small particles that contain proteins and often occur as crystals
Size	about 0.0001 cm	about 0.0000001 cm
Food	live or dead organic material	special cells of a live host
Transport of nutrients	by absorption	by absorption
Reproduction	by cell division	by duplication of the particles

Spelling list

bacteria
bacterium
flagella
immunize
organism
Pasteur
pasteurization
petri dish
pneumonia
putrefy
spiral
spontaneous
sterilize
syphilis
toxin
tuberculosis
typhoid
vaccine
virus
yoghurt

Things to do

21.5 Make some yoghurt at home. First prepare about half a litre of skim milk (a little more concentrated than the instructions direct). Heat the milk almost to boiling and then allow it to cool to 40°C. Stir in a small carton of plain yoghurt and transfer to a thermos flask. Leave overnight and refrigerate the next day.

21.6 Investigate the souring of milk. Pour samples of fresh milk into three clean test tubes. Plug the first with cottonwool and leave in a warm place. Boil the milk in the second tube for five minutes, plug the tube and put it with the first one. Plug the third sample with cottonwool and place it in a refrigerator. Observe the three over a number of days.

21.7 Make a compost heap in a kerosene tin. Open the top of the tin and punch some drainage holes in the side about 1.5 cm from the bottom. Add chopped-up green plant material to a depth of 10 cm. Cover with about

2.5 cm of rich damp garden soil. Add more plant material and soil in layers until the depth is about 30 cm. At weekly intervals make the following observations:

(a) Take the air temperature and the temperature of the middle of the heap.
(b) Open the heap a little and look for evidence of decay. Look for any thread-like fungi.
(c) Note any animals found in the heap.
(d) After several weeks, try to detect any gases or fumes produced.
(e) Take samples and examine them with a microscope.

More questions

21.8 What are the principal agents of decay? Why are the processes of decay important in nature?

21.9 Why is it that organisms of decay do not develop in foods that contain a high concentration of sugar or salt?

21.10 How do bacteria "grow"?

21.11 Some bacteria are able to survive highly adverse conditions, such as very high temperatures. What species adaptation enables them to do this? (R)

21.12 What defences have our bodies against the invasion of germs? How do they protect the body?

21.13 Why do we normally contract certain diseases only once during our lifetimes?

21.14 Why is it difficult to classify a virus as an organism?

21.15 What causes decay in teeth? Why does cleaning your teeth reduce the chances of decay? Is toothpaste really necessary? (R)

21.16 Write short accounts of the work of
(a) Robert Koch
(b) Edward Jenner
(c) Louis Pasteur
(d) Joseph Lister
(e) Alexander Fleming
(f) Sir Macfarlane Burnett. (R)

21.17 Polluted canals and rivers are often foul-smelling. This effect is due to anaerobic bacteria. What are they and how do they cause the foul smell?

21.18 Concrete sewer pipes corrode after a time, because of the action of anaerobic bacteria. Find out how ventilation pipes help to reduce this kind of corrosion. (R)

21.19 Use your library to find out about old methods of food preservation. (R)

21.20 In former times surgeons were interested in antisepsis. Today they work in aseptic conditions. What is the difference? (R)

21.21 Antibiotics are not dispensed without a doctor's prescription. Why? (R)

21.22 Poliomyelitis is controlled by the Salk vaccine. Why did it take such a long time to develop this vaccine? (R)

21.23 Do bacteria have anything to do with
(a) treatment of sewage?
(b) production of pimples?
(c) production of body odour?
(d) food-poisoning?
Write a paragraph in answer to each question. (R)

Test yourself (chapter 21)

Write the answers in your workbook.

1. Name the three main groups of bacteria.
2. Name two agents of decay.
3. The two main parts of soil are mineral matter and humus. What is humus?
4. Which is the larger — a bacterium or a virus?
5. State one important way in which the body protects itself against disease.
6. Mark each of the following statements as being either true or false.
   (a) All bacteria are harmful.
   (b) Viruses cannot reproduce.
   (c) A virus can live only in the cells of other living things.
   (d) A bacterium can be seen through an ordinary light microscope.
7. Louis Pasteur investigated the disease anthrax in an area where it was killing sheep. Label each of the following sentences, (a) to (e), as being a statement or action of one of these kinds:
   - an hypothesis
   - an observation
   - a scientific law
   - an experiment
   - an experimental result.

   Each label may be used more than once.
   (a) Pasteur noticed patches of soil of a different colour from the rest. These were in places where sheep that had died from anthrax were buried.
   (b) The idea came to Pasteur that worms travelling from the depths of the soil brought soil from around a carcass to the surface.
   (c) This soil would probably contain anthrax-producing bacteria.
   (d) He inoculated some guinea pigs with soil taken from inside these worms.
   (e) The guinea pigs contracted anthrax.

Choose the best answers to questions 8 and 9 and write the letters in your workbook.

8. A scientist is puzzled by a disease infecting a certain plant crop. He crushes some infected plants and extracts a clear juice. No cells are visible in this juice under a light microscope. If a little of the juice is injected into healthy plants, they develop the disease. The scientist concludes the disease is caused by
   (a) a bacteria
   (b) a virus
   (c) a fungus
   (d) microscopic animals.
9. In order to find out if his experimental results were true, a scientist wanted to test a certain vaccine as a protection against a tropical disease. He chose a large village with a population predominantly native but containing a few Europeans. The best way to test the effectiveness of his vaccine would be to
   (a) give the vaccine to only those people suffering from the disease and watch the results
   (b) give the vaccine to the whole population and watch the results
   (c) give the vaccine to half the natives and half the Europeans and watch the results
   (d) give the vaccine to the natives but not to the Europeans and watch the results.

22

Drugs

What are drugs?

The word "drug" can have a number of different meanings. To some people it simply means a medicine used by a doctor in the treatment of disease. To others it means a substance the use of which is illegal, or frowned on by the community. Some consider alcohol, tea, and coffee to be drugs. To others these are only beverages, not to be confused with substances such as marijuana and heroin.

In this discussion we shall use the word "drug" to mean a mind-altering substance, that is, a substance that changes sensation, mood, consciousness, or behaviour. In this sense we must include alcohol, tea, coffee, tobacco, and aspirin as drugs.

How old are drugs?

Mind-altering drugs have been used by mankind throughout recorded history. As far back as 2737 B.C., marijuana appeared in a pharmacy book written by the Chinese emperor Shen Nung.

The Aryan conquerors of India, in about 1500 B.C., commonly ate the sap of a particular mushroom because it produced hallucinations. The sap contains a substance similar to LSD. It has been suggested that Alice, in Wonderland, chewed the same kind of mushroom.

Cocaine was first extracted from leaves of coca trees brought back from South America at the time of the Spanish conquest. The Spaniards had noticed South American Indians chewing the leaves to get "high".

Who are drug-users?

Peoples all over the world use drugs. Western civilization has a way of life that depends heavily on them. If we include alcohol, tea, coffee, tobacco, and aspirin, it would be safe to say we are practically all drug-users. In fact, it would be difficult to find a person who does not take a mind-altering drug of some kind.

The nervous system and the mind

Chapter ten was about the nervous system and coordination. In it we described how messages are carried to the brain by sensory neurones and from the brain by motor neurones. The messages are actually electrical pulses that jump from the axon of one neurone to the dendrites of the next. The speed of these pulses through the system is about 50 metres per second. In other words, it takes time to act and think.

Experiment 22.1 gives some evidence that the messages are electric currents and experiment 22.2 demonstrates the time lag between stimulus and response.

The human brain contains about one million million neurones. Unlike those leading to and from the brain, these neurones have short axons and dendrites. Their arrangement is extremely complex. It can be likened to a massive archway between incoming sensory neurones and outgoing motor neurones. Figure 22.1 gives some idea of this.

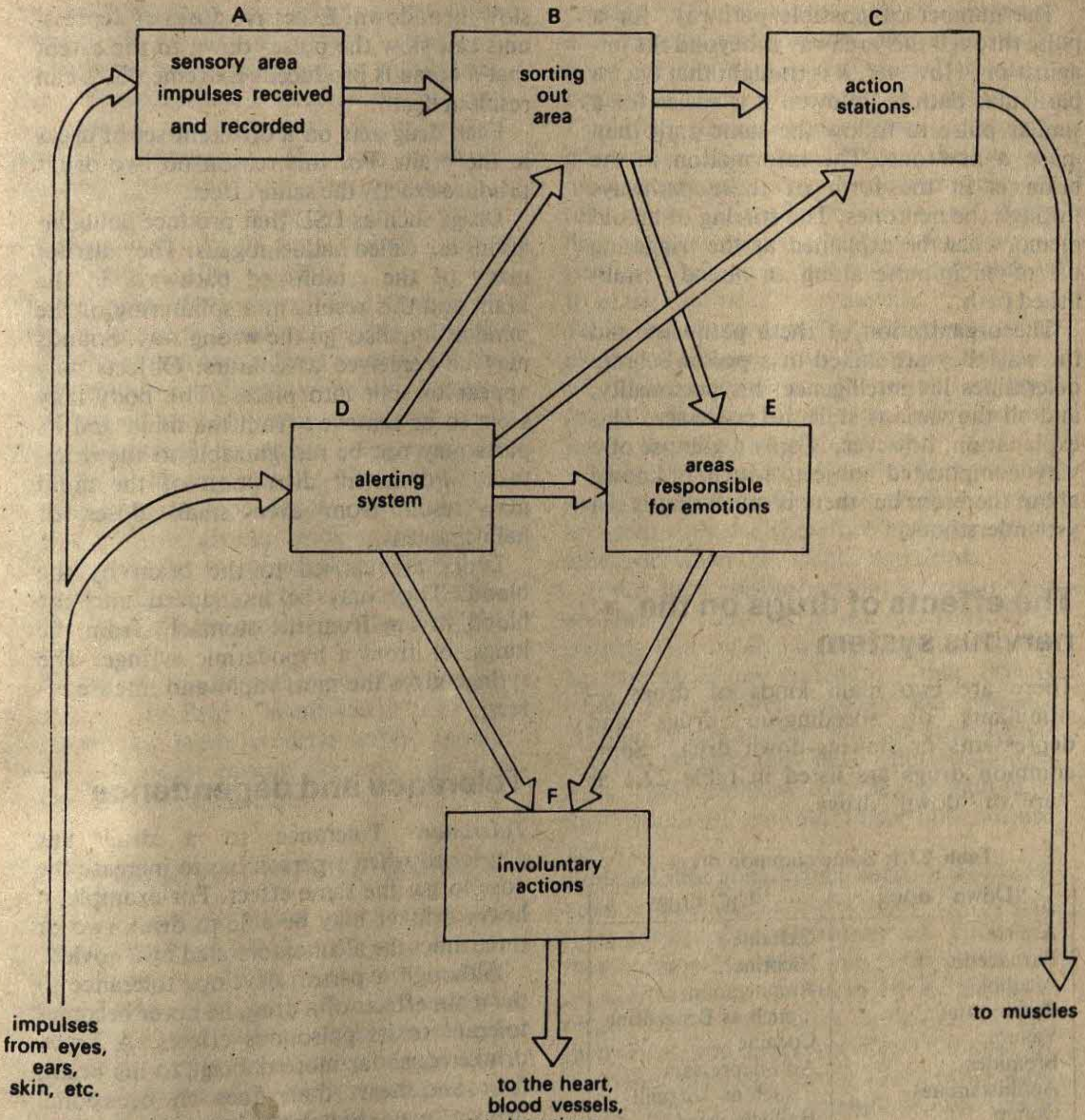

A
sensory area impulses received and recorded
B
sorting out area
C
action stations
D
alerting system
E
areas responsible for emotions
F
involuntary actions
impulses from eyes, ears, skin, etc.
to muscles
to the heart, blood vessels, intestines, glands, etc.

Figure 22.1: A diagram to indicate the complex way the brain can respond to a sensory impulse. Imagine what goes on in the brain of a mother when she sees her young child run out on to a busy road. Her whole brain is alerted, more adrenalin is pumped into her blood stream, her heart beats faster, she feels fear and her muscles carry her body out on to the road in an attempt to help the child.

The number of possible pathways for a pulse through this archway is beyond the imagination. However, it is thought that once a particular path is followed it is easier for a similar pulse to follow the same path than make a new one. The information in the brain is in the form of these pathways through the neurones. The stirring of an old memory can be explained as the triggering off of an impulse along an already established path.

The organization of these pathways and the way they are linked in a person's brain determines his intelligence, his personality, and all the various skills he possesses. This explanation, however, is only a glimpse of a very complicated subject. Much is known about the brain but there is much that is not yet understood.

The effects of drugs on the nervous system

There are two main kinds of drugs — stimulants or speeding-up drugs and depressants or slowing-down drugs. Some common drugs are listed in table 22.1 as "up" or "down" drugs.

Table 22.1: Some common drugs

"Down" drugs	"Up" drugs
Aspirin	Caffeine
Phenacetin	Nicotine
Alcohol	Amphetamines such as Benzedrine
Barbiturates	Cocaine
Valium	Anti-depressants such as Tofranil
Bromides	Hallucinogens such as LSD
Antihistamines	
Opium	
Heroin	
Glue gases from paint thinners	
Tranquillizers such as Largactil	
Marijuana (which has hallucinatory side effects)	

Stimulants speed up the electrical pulses through the nervous system; depressants slow them down. Excessive doses of depressants can slow the pulses down to the extent that a coma is produced. Extreme doses can result in death.

Each drug acts on a different set of areas in the brain. For this reason no two drugs produce exactly the same effect.

Drugs such as LSD that produce hallucinations are called hallucinogens. They disrupt many of the established pathways in the brain and this results in a splintering of the mind as impulses go the wrong way. Sounds may be perceived as colours. Objects may appear to split into pieces. The body may seem to be removed from the mind and its parts may not be recognizable to the drug-taker. Permanent disruption of the mind may result from even small doses of hallucinogens.

Drugs are carried to the brain by the blood. They may be introduced into the blood stream from the stomach, from the lungs, or from a hypodermic syringe. The syringe gives the most rapid and intense effect.

Tolerance and dependence

Tolerance. Tolerance to a drug has developed when a person has to increase the dose to get the same effect. For example, a heavy drinker may be able to drink two or three times the alcohol tolerated by a novice.

Although a person develops tolerance to the main effects of a drug, he never becomes tolerant to its poisonous effects. A heavy drinker does far more damage to his brain, liver and heart than does an occasional drinker, even though the latter may become more intoxicated.

Reverse tolerance. Some drugs, like LSD, produce what is called reverse tolerance. A user of LSD finds that, with successive doses, the same effects are produced by taking less and less.

Physical dependence. A person is physically dependent on a drug if he experiences physical withdrawal symptoms when he stops taking the drug. These withdrawal symptoms are generally the reverse of the effects of taking the drug itself. For example, a person tolerant to heroin, a "down" drug, experiences severe stimulations on withdrawal. The nervous system is acutely aroused and the patient becomes both mentally and physically overactive. This can result in sweating, shivering, and even convulsions. In the case of an alcoholic, the physical withdrawal symptoms may include violent hallucinations called the DTs.

Psychological dependence. This means that the drug-user has developed a chronic habit. A person withdrawing from a drug may experience severe physical symptoms. It might be imagined that the person is cured when these symptoms disappear. However, the craving for the drug persists. This is the basis of psychological dependence. For example, a person trying to give up smoking is not worried so much by the physical withdrawal effects as by the yearning to have a cigarette in order to satisfy the craving produced by the habit.

Assistance from doctors and social workers in the field of mental health may be necessary to break a drug habit. Group therapy amongst people similarly addicted can be useful in some cases.

Reasons given for using drugs

The following are the most common reasons given by drug-users for taking drugs.

For social pleasure. One of the most widely accepted uses of alcohol is to make it easier to mix with and talk to other people. It comes as a surprise to many to be told that alcohol is a depressant. "It stimulates me," they say. "How can it be a depressant when it makes me talk?" The answer is that a small dose of alcohol reduces emotional tension. It has a relaxing effect, so that inhibitions are removed. Increased doses carry the relaxing effect further and, if sufficient, produce sleep and finally coma.

Marijuana is often used socially for the same purpose as alcohol.

For individual pleasure. Many people who use marijuana say they do it simply for pleasure. They say it is relaxing, and increases self-confidence, sensual awareness and sensory appreciation. For example, it gives increased pleasure when looking at beautiful scenery or listening to music.

Curiosity, desire to experiment, sense of adventure. These are perhaps the reasons most commonly given for commencing to take drugs. There is no doubt that many drug-users started by looking for new experiences, out of a desire for some change from the routine of everyday life.

To be one of a group. In some countries the use of marijuana is an admission ticket to the "in" youth culture. It may be very hard for an individual to resist group pressure to join in the activities of the group.

Many children grow up with the idea that smoking and drinking are adult practices and that they are therefore behaving in an adult way when they smoke and drink.

It has been established that teenagers who are heavy users of drugs generally have parents who are also heavy users. One has to be careful about concluding that this is evidence of children "aping" their parents. It could be that parents who use drugs heavily do so because they have emotional problems. These problems may be transmitted to their children, causing them also to use drugs.

Self-understanding. Some users of LSD and other hallucinogens claim these drugs give them transcendental experiences. They feel they become detached from their bodies and are able to see themselves in a new light. As a result they are better able to accept themselves and other people. This kind of discovery has often been made in other ways in the past — through religious experience, for instance.

To relieve tension and anxiety. A businessman may drink to steady his nerves before making an important business deal. A student may take tranquillizers before an examination for the same reason.

Many people find themselves in a chronic state of depression, anxiety, boredom, overaggressiveness, or some other distracting emotional disturbance. This is generally due to unsatisfactory conditions in their everyday lives. Most would benefit from proper psychiatric treatment. But they do not seek it because they either don't see themselves as needing it or don't understand that such treatment can help them. Some find relief by resorting to drugs and are thus able to carry on their lives in a makeshift kind of way.

Some consequences of drug use

Overdoses of depressant drugs can cause death through depression and eventual stopping of breathing. There is a special danger of this happening if two depressant drugs are taken at the same time, for example, barbiturates and alcohol. Additive effects of drugs are responsible for many deaths, either accidental or suicidal.

Alcoholics tend to replace eating with drinking and so tend to have problems of malnutrition. They also suffer degeneration of areas of the brain, the heart muscles and the liver. Degeneration of the brain causes loss of mental faculties such as memory, thinking and learning.

Closely controlled tests show that even small amounts of alcohol decrease alertness. However, the subject being tested feels more alert than if cold sober. Under these conditions his judgment is impaired and accidents may result.

Tobacco-smoking damages the respiratory tract, including the lungs. Evidence also exists to show that tobacco smokers are greater risks for heart disease and lung cancer.

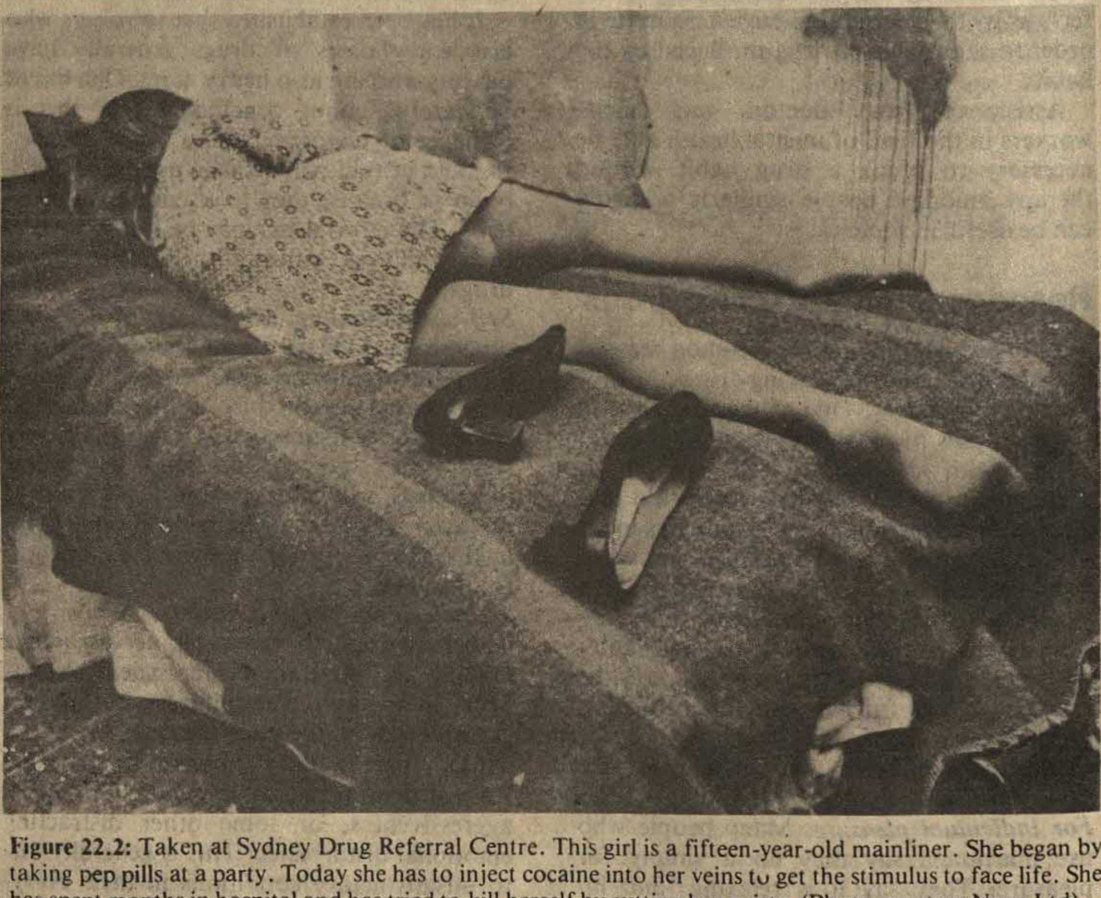


Figure 22.2: Taken at Sydney Drug Referral Centre. This girl is a fifteen-year-old mainliner. She began by taking pep pills at a party. Today she has to inject cocaine into her veins to get the stimulus to face life. She has spent months in hospital and has tried to kill herself by cutting her wrists. (Photo courtesy News Ltd)

Figure 22.3: A drug addict being carried out of her home by a drug squad detective. The unconscious girl will be taken from here to a hospital where doctors will try to save her life. (Photo courtesy News Ltd)

Hallucinogens, such as LSD, bear a close chemical resemblance to the substance in the brain that transmits pulses from one neurone to the next. This could explain why hallucinogens absorbed into the brain can switch impulses on to the wrong paths. LSD is not safe to use because of the risk that these wrong pathways could become established. This means that hallucinations could be experienced by a drug-user at any time, even without taking the drug.

Physical withdrawal effects have been discussed earlier. These can be extremely severe, as in the case of a heroin addict when he cannot get the drug.

Psychological effects. You have probably heard of people addicted to playing poker machines. Such people, in a room with the machines, feel drawn to play them and to keep on playing them. This is psychological dependence. Another example is the behaviour of the person who must have an APC powder before he starts work in the morning.

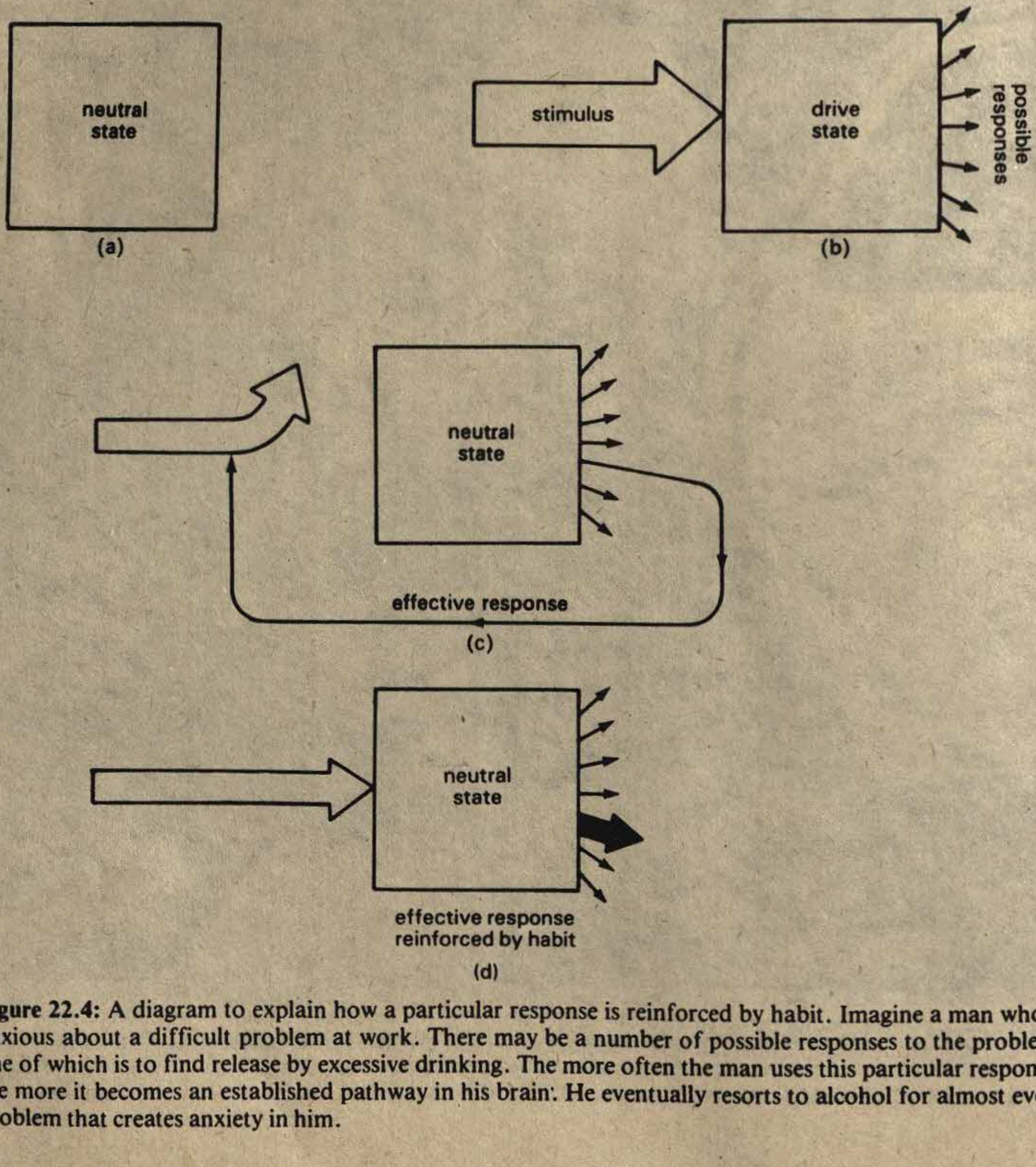


Figure 22.4: A diagram to explain how a particular response is reinforced by habit. Imagine a man who is anxious about a difficult problem at work. There may be a number of possible responses to the problem, one of which is to find release by excessive drinking. The more often the man uses this particular response, the more it becomes an established pathway in his brain. He eventually resorts to alcohol for almost every problem that creates anxiety in him.

In drug-taking, psychological dependence is often more serious than physical dependence. Physical withdrawal reactions may be severe but usually last only a week or so. Psychological dependence is stamped on the mind and is much more difficult to eradicate. Many an alcoholic, after being cured in hospital, returns to his or her drinking habits shortly after discharge.

One explanation of psychological dependence is given in figure 22.4. When a person is relaxed and at rest he is said to be in a neutral state. A stimulus places him in a drive state. The stimulus can be a simple one such as hunger. The only response that will alleviate this drive state is eating. Having satisfied his hunger the person returns to his neutral state once more.

However, many drive stimuli are not so simple. A person may be anxious about a problem at work. There may be a number of possible responses to this drive state. He can discuss the problem with his boss, contact a friend who does similar work, apply for another job or find release by excessive drinking. The more often he uses this latter response, the more it becomes an established pathway in his mind. Eventually he resorts to this type of response for almost every problem creating anxiety.

It is obvious that the behaviour just described reduces the chances of learning to overcome problems with more constructive responses. These responses may be more demanding at first but will be more gratifying later.

Attitudes to drugs

Drug-taking can pose many problems. Not all of these are caused by the drugs; many centre around attempts to prevent people from harming themselves by drug abuse. Situations created by both types of problems can only be relieved by calm discussions without prejudice.

Recently in a girls' secondary school near Sydney, a Year 9 student tried to sell some pills to her classmates. Several girls told their parents about it and, as a result, the matter was raised at a regular meeting of parents.

A number of parents spoke very emotionally on the matter and wanted to know what the principal had done about it. The following are some of the statements made at the meeting.

- "Were the police notified? I think the girl should have been expelled and handed over to the police."
- "What sort of pills did the girl have? How did she get them? Has she attempted this before?"
- "I think the less said about the incident the better. The solution to the problem should be a matter between the headmistress, the girl and her parents."
- "This sort of thing could be going on all over the school. I think periodical surprise checks should be made on the possessions of every girl in the school."

The principal told the meeting that someone had phoned a TV station about the incident and that people at the station had asked her for an interview. She had refused.

Questions

22.1 How do you think the incident should have been handled? Was the principal right in refusing an interview with the TV station? Why?

22.2 Imagine you are a parent of the girl trying to sell the pills. How would you deal with the situation?

22.3 Imagine you are the girl "pusher". What are the various reasons you have for wanting to sell the pills?

22.4 Suppose the girl had been seen selling alcoholic beer at a school sports meeting. Would the same amount of concern have been created?

Alcohol: the number one killer

The above heading appeared in a recent Sunday newspaper. The following five points are a summary of the statements made in the article under the heading.

1. Alcohol is a drug of addiction. In some areas 15 per cent of the population are alcoholics.
2. Alcoholism is the cause of many broken families.
3. Alcohol is a major cause of road accidents.
4. Alcoholism causes absenteeism from work. This results in loss of wages and even loss of jobs. This lowers the living standards of the families affected.
5. Excessive alcohol is damaging to both the mental and physical health of the individual.

Questions

22.5 Do you think alcoholism is one of Australia's commonest diseases?

22.6 List as many reasons as you can think of for a person's becoming addicted to alcohol.

22.7 Think about the families you know. What are their recreations? Do any members of these families depend excessively on alcohol?

Should marijuana be legalized?

Marijuana consists of the leaves, flowers and stems of the plant *Cannabis*. Hashish is a resinous material obtained from the flowers of *Cannabis*. Hashish is the most potent form of marijuana. Pot and hash are nicknames for the drug.

Marijuana is not a drug of physical dependence. There are no physical effects on withdrawal. However, marijuana can produce psychological dependence.

At present it is illegal to use marijuana in Australia. The penalty that may be imposed for having it in one's possession is imprisonment for up to 2 years and a fine of up to $2000.

Some people argue that it is a mistake to ban marijuana. They give the following reasons to support their case.

- Many young people start using marijuana out of a sense of rebellion, because it is illegal. Legalize it and the urge to take it will, in many cases, disappear.
- Marijuana does no more harm than alcohol or tobacco.
- Alcohol is doing much more harm to individuals and society than marijuana. We are therefore hypocrites if we accept alcohol but hold up our hands in horror at the thought of people using marijuana.
- People who use marijuana are not harming others. The law should not prevent people doing things that have no effect on others.

The following are some of the arguments people give against legalizing marijuana.

- We have a major community problem with alcohol. Why add another to the list?
- Advocates of marijuana say it causes less damage to health than alcohol or tobacco. We do not know this for sure because it is difficult to conduct tests when it is illegal to use the drug.
- Marijuana creates a feeling of well-being. It relaxes the user and suppresses the memory of the immediate past. Many people use it as an escape from problems of day-to-day living. Eventually these people cease to work and expect the state to support them.
- Marijuana is often a step towards the taking of hard drugs such as heroin.
- Very few people use marijuana — a recent survey indicated that about 5% of the population use it. Why increase this proportion by legalizing it?

Question

22.8 What is your opinion? Would you like to see marijuana legalized? Why?

EXPERIMENT

22.1

Can an electric current cause response in a muscle?

Each group will need:

- frog
- scissors
- scalpel
- dissecting needle
- dry cell
- wires

What to do

- Anaesthetize a frog by placing it in a jar with a little chloroform. Alternatively, kill it instantly by piercing its brain with a needle.
- Cut off its head and place the body in water for about an hour.
- Dissect it to expose the sciatic nerve. This can be seen as a white cord lying between the thigh muscles above the knee. (See figure 22.5.)

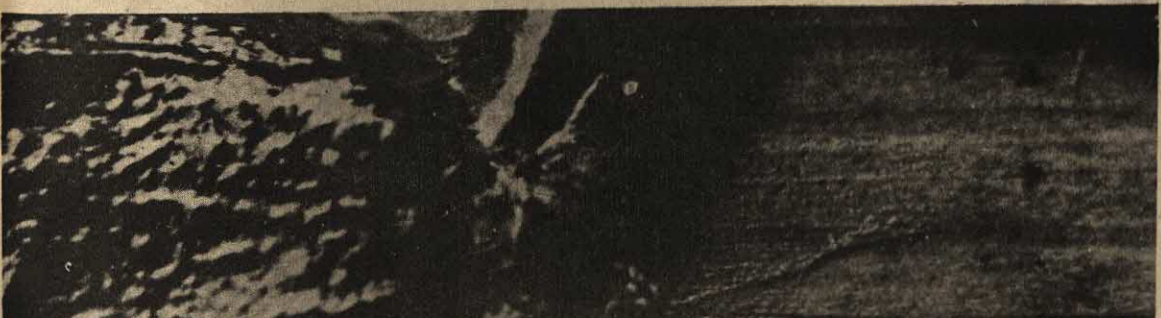


Figure 22.5: Dissecting the leg of a frog to expose the sciatic nerve. The frog is lying on the board with its back uppermost. Scissors are the most useful tool for dissection.

- Cut the nerve near the hip and rest it lightly on the muşcle.
- Connect two wires to a small battery and place the ends of the wires on the nerve.

Questions

22.9 What happened when the battery was connected to the sciatic nerve? What kind of a response is this (remembering that the brain of the frog has been removed)?

22.10 Were you able to stimulate other parts of the body?

22.11 Write a conclusion about the experiment.

What is a person's reaction time when responding to the switching on of a light?

EXPERIMENT

22.2

Each group will need:

- stop clock
- power pack
- lamp and socket
- battery to operate the lamp (The lamp could be operated from the power pack if it worked on the same voltage as the clock.)
- press-button switch
- double-pole single-throw switch
- connecting wire

What to do

- Set up the apparatus as shown in figure 22.6.

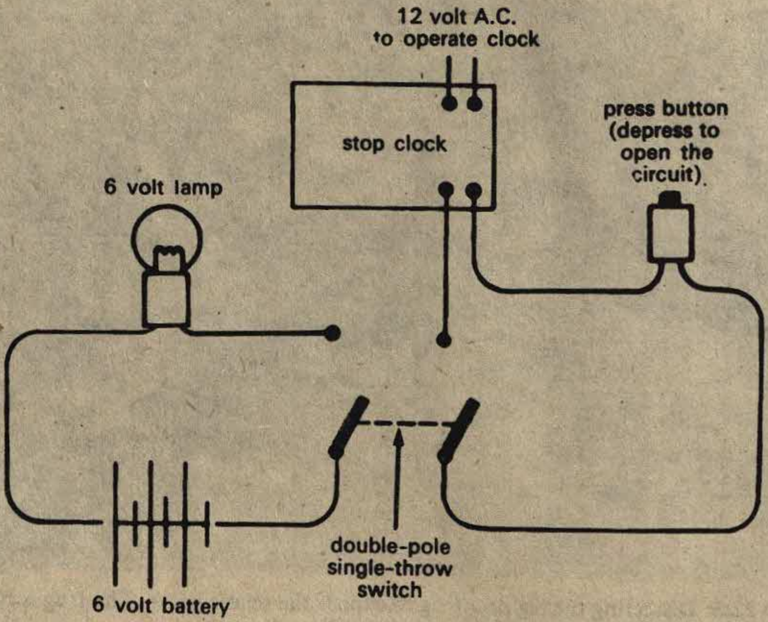


Figure 22.6: Circuit of apparatus to measure reaction times.

- Place your hand flat on the table next to the button.
- Signal your partner when you are ready. Your partner should be screened from view so that you cannot see the working of the switch.
- When the light comes on, press the button with your thumb.
- Read and record your reaction time. Replace your hand flat on the bench.
- Repeat ten times and find the mean of all your reaction times.

Questions

22.12 Does your reaction time shorten with practice?

22.13 Suppose a car is moving at 60 km/h. How far does it travel in your reaction time?

22.14 How would reaction time be affected by taking a depressant drug?

Drugs

- A drug is a mind-altering substance.
- Drugs have been in use since prehistoric times.
- Practically everybody uses mind-altering drugs of some kind.
- The brain contains millions of neurones.
- Stimuli follow intricate pathways through the neurones of the brain.
- Stimulants are speeding-up drugs, depressants are slowing-down drugs.
- Tolerance to a drug has developed when more of it is required to produce the same effect.
- Drug dependence may be physical or psychological or both.
- Excessive drug-taking can harm a person both physically and psychologically.

Spelling list

anaesthetize
aspirin
dependence
depressant
hallucination
hallucinogen
illegal
legalize
marijuana
poisonous
psychology
withdrawal

Things to do

22.15 Read about the history of prohibition of alcohol in the U.S.A. What problems did prohibition create? Why was the prohibition act eventually repealed?

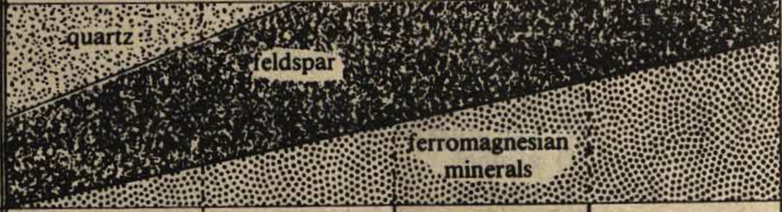
22.16 Have a class debate on the subject "Talking about drugs tends to lead young people to try them."

22.17 Conduct two surveys about cigarette smoking — on the reasons for starting to smoke and the reasons for stopping. Duplicate sheets of reasons (two sample sheets are given on p. 276), and arrange for the class to obtain responses from other classes and from students' families.

Appendix 1: some additional information

Chapter 2

Igneous rocks

Colour	Light-coloured minerals predominate		Dark-coloured minerals predominate	
Mineral composition				
Coarse-grained	granite	syenite	diorite	gabbro
Medium-grained	quartz porphyry	various other porphyries		dolerite
Fine-grained	rhyolite	trachyte	andesite	basalt

Chapter 11

Photosynthesis

In the text of chapter 11 the chemical equation to represent photosynthesis is given as

$$6CO_2 + 6H_2O + \text{light energy} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

According to this equation, the oxygen formed during the reaction comes either wholly or partly from the carbon dioxide. It cannot all come from the water.

Experiments using radioactive oxygen as a tracer prove this to be wrong. The oxygen liberated during photosynthesis comes solely from the water taking part in the reaction. Therefore, the correct equation is

$$6CO_2 + 12H_2O + \text{light energy} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

This equation seems strange because it shows H_2O on both sides, but nevertheless it is correct.

Chapter 19

Preserving specimens of invertebrates

Sponges. These may be dried and stored in boxes.

Coelenterates. Freshwater *hydra* can be collected and kept in an aquarium. Jellyfish, bluebottles and sea anemones can be preserved in 70 per cent alcohol. Sea anemones should first be placed in salt water containing magnesium sulphate, to relax their tentacles.

Worms can be preserved in 70 per cent alcohol. They should first be tied to a microscope slide or a strip of plastic to prevent them from collapsing into a heap at the bottom of the jar.

Echinoderms are readily killed in fresh water and can be dried out. Before drying them out, place them in 70 per cent alcohol for a few days or they will lose their spines.

Molluscs. If required, the body of a marine mollusc can be removed by boiling the animal in salt water and pulling the body out with wire.

Arthropods. Crustaceans, millipedes, centipedes, spiders and many kinds of insects can be preserved in 70 per cent alcohol. A millipede, for example, should be first tied to a piece of glass before it is bottled in alcohol.

Animals like butterflies may be killed by pinching the body under the wings. They can then be mounted on a board with pins. Many species of arthropods can be preserved by pinning to a board.

A killing jar is useful for killing spiders and very small arthropods. A large screw-top jar makes a good killing jar. Place a mixture of sawdust and potassium cyanide (2 to 1 by volume) in the bottom and cover with a one-centimetre layer of plaster of Paris. Place a piece of tissue paper in the jar to give the animals something to hold on to.

Chapter 21

Preparation of nutrient jelly

Ingredients: peptone 2.5 g
beef extract 1.5 g (¼ Maggi cube)
agar 10.5 g

Bring 500 mL of water to the boil and add the agar. Stir until dissolved. Add the peptone and stir until dissolved. Add the beef extract and stir until dissolved.

Pour into five 100 mL flasks. Plug with cottonwool and sterilize by heating in a pressure cooker for 20 minutes.

Appendix 2: answers to selected questions

Chapter 2

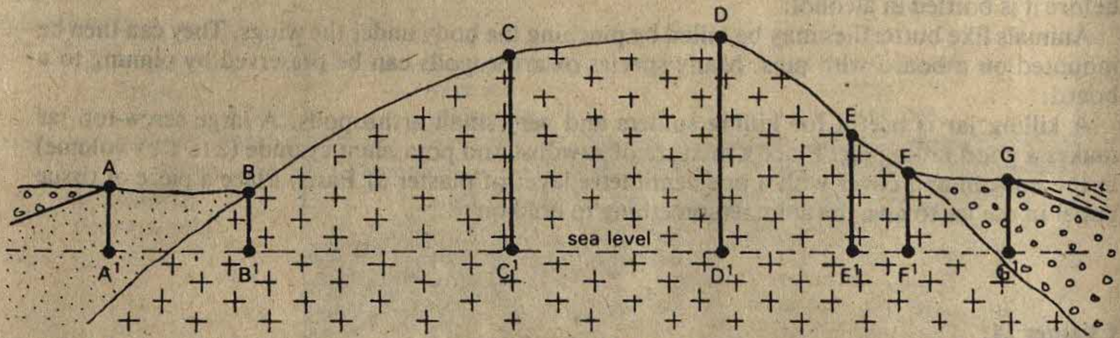


Figure 2.12: This drawing is the answer to experiment 2.2. From the information given in the experiment, there is no indication of the underground boundaries of the batholith. But seeing that batholiths are formed underneath sedimentary rocks, we can assume that it will be wider below ground level. The rocks on either side of the batholith will not be ordinary sedimentary rocks. They will have been changed by the heat of the granite.

Chapter 15

15.10 **(a)** 15 min
  (b) 30 min
  (c) 5.3 km/h
15.11 **(a)** no
  (b) yes
  (c) no
  (d) 2 m/s^2
  (e) 1 m/s^2
15.14 72 km/h, 144 km/h
15.15 2.5 m/s^2 and 3.0 m/s^2
15.16 48 km/h, 240 m
15.18 3.3 s
15.19 168 m
15.20 4 s approx. (earth), 9 s approx. (moon)
15.21 **(a)** 5 m **(b)** 20 m
  (c) 45 m **(d)** 5 m
  (e) 15 m **(f)** 25 m
15.22 31 m (approx.)

Chapter 16

16.4 2 m/s^2, 8 N, 0.2 m/s^2, 4 m/s^2, 25 kg, 1 N
16.6 **(a)** 25 m
  (b) 10 m/s
16.7 10 m/s
16.8 3 m/s
16.9 6000 N

Chapter 17

17.6 the car
17.7 1.2 m/s
17.14 4 tonnes force

Chapter 18

18.13 Table A: 200 J, 20 m, 10 N, 50 J, 0.5 N
  Table B: 2000 J, 2 m, 2 kg, 400 J
  Table C: 125 J, 500 J, 10 m/s, 7 m/s, 2 kg
  Table D: 25 W, 20 W, 2400 J, 120 000 J, 0.03 min
18.14 2 J
18.15 11.25 m
18.16 22 m/s (approx.)
18.17 ball at height of 1 m
18.18 450 000 J
18.19 4000 J, 1.3 kW
18.20 **(a)** 56 250 J
  (b) 56 250 J
  (c) 11.25 kW (average)

Appendix 3: answers to tests

Chapter 1

1. **(a)** tuff
   (b) basalt
   (c) pumice
   (d) obsidian
   (e) rhyolite
   (f) volcanic breccia
   (g) volcanic agglomerate
2. In breccia the fragments are angular, whereas in conglomerate they are rounded.
3. basalt
4. (c)
5. B

Chapter 2

1. rhyolite
2. gabbro
3. (a)
4. (c)
5. (d)
6. (c)
7. (b)
8. (a)
9. (b)
10. (b)

Chapter 3

1. 2.5 m from fulcrum
2. **(a)** force magnifier
   (b) force magnifier
   (c) force magnifier
   (d) force magnifier
   (e) force magnifier near fulcrum, movement magnifier at the ends of the blades
   (f) movement magnifier
   (g) force magnifier
3. Because the handle is wider than the blade.
4. magnification of force
5. **(a)** 20 cm
   (b) 400 kg
   (c) 350 kg
6. (b), (c) and (d). Machine (a) would not, because of friction and inertia.
7. **(a)** force
   (b) 2
   (c) 240 force units
8. Author prefers (c).

Chapter 4

1. Assists movement, and provides support for the body and protection for the organs.
2. **(a)** gristle
   (b) in the moving joints, where ribs join the breastbone, in the oesophagus and in external parts of the ears and nose
3. Y shortens and becomes fatter, X lengthens and becomes thinner.
4. **(a)** yes
   (b) no
   (c) yes
   (d) yes
5. (c)
6. (d)
7. (d)

Chapter 5

1. reptiles
2. reptiles
3. It lays eggs.
4. It has no backbone.
5. lung
6. Reptiles have developed internal fertilization, a water-tight egg covering, and scaly skin that reduces loss of water, and they have lost the larval stage of the life cycle.
7. (c)
8. (d)
9. (a)
10. (b)
11. (c)

Chapter 6

1. (d)
2. (c)
3. (b)

Chapter 7

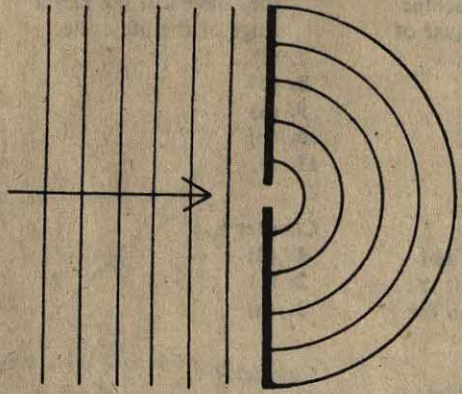
1. violet
2. (b)
3. red
4. **(a)** white
   (b) red
   (c) blue
5. **(a)** blue
   (b) black
   (c) blue
6. **(a)** red
   (b) red
   (c) black
7. **(a)** red
   (b) red
   (c) black
8. The pullover is not pure blue; the blue colour of the wool contains some green.
9. black
10. The three bands would appear to be
    (a) black, red, red
    (b) blue, blue, black
    (c) black, green, black.

Chapter 8

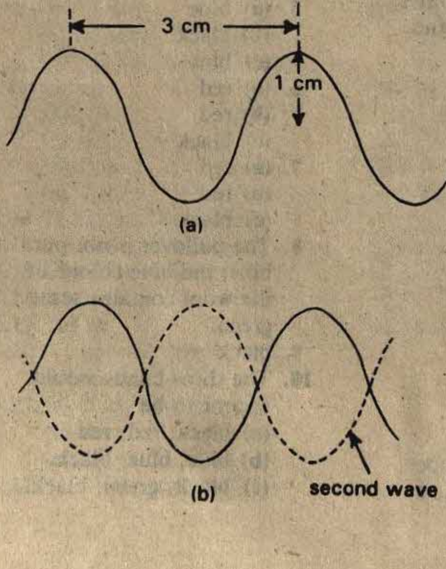
1. **(a)** real, diminished
   (b) real, magnified
   (c) real, diminished
   (d) virtual, magnified
   (e) real, magnified
   (f) real, diminished
2. (d)
3. (a)
4. (c)
5. (d)
6. (d)

Chapter 9

1.



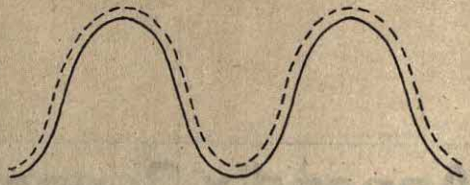
2.



(a)

(b)

3.



4. A light wave is polarized when the oscillations of the wave are taking place in only one plane.
5. Polaroid glasses reduce glare because the light reaching the wearer's eyes has been polarized.

Chapter 10

1. A nerve contains a bundle of neurones in a sheath.
2. (a), (c), (f)
3. **(a)** axon
   (b) dendrite
4. medulla
5. that part of the cerebrum called the cortex
6. **(a)** reflex
   (b) sensory neurone
   (c) spinal cord (spine)
   (d) muscle
7. **(a)** pancreas
   (b) insulin
8. **(a)** pituitary
   (b) base of the brain

Chapter 11

1. root, stem, leaf, bud, flower
2. xylem tissues
3. phloem tissues
4. stomates
5. carbon dioxide and water
6. oxygen and glucose
7. respiration
8. the sun
9. chloroplasts
10. (b)
11. (c)
12. (a)
13. (c)
14. (d)
15. (b)
16. (b)
17. (b)
18. (a)

Chapter 12

1. detritus
2. zooplankton
3. phytoplankton
4. (a) energy
   (b) reduced
5. plant
6. (c)
7. (a)

Chapter 13

1. pollination
2. fertilization
3. zygote
4. (a) anther
   (b) stigma
   (c) petal
   (d) ovary
   (e) sepal
   (f) receptacle
5. (b)
6. (c)
7. (c)
8. (d)

Chapter 14

1. (a) kidney
   (b) seminal gland
   (c) bladder
   (d) vas deferens
   (e) anus
   (f) ureter
   (g) prostate gland
   (h) urethra
   (i) penis
   (j) testis
   (k) scrotum
   (l) kidney
   (m) ovary
   (n) uterus
   (o) vagina
   (p) ureter
   (q) oviduct
   (r) bladder
   (s) urethra
   (t) anus
2. placenta
3. in the uterus
4. after birth
5. (b)

Chapter 15

1. 6.7 km/h
2. (a) 1.25 m/s^2
   (b) 90 m
3. (a) 150 km
   (b) 50 km/h
   (c) zero
   (d) 25 km/h
   (e) 50 km/h
   (f) zero
4. (a) Yes, between 3.5 and 4 seconds. (Graph is horizontal.)
   (b) Yes, between 2 and 2.5 seconds.
   (c) 80 km (approx.)
5. It takes the car 3 seconds to stop. In 3 seconds it travels 36 metres. The answer is "no".

Chapter 16

1. (a) 12 m/s^2
   (b) 1.3 m/s^2
2. (a) 200 N
   (b) 2 m/s^2
   (c) 8 m/s
   (d) 4 m/s
   (e) 16 m

Chapter 17

1. mass
2. car B
3. 6400 km
4. (c)
5. (c)
6. (b)
7. (c)

Chapter 18

1. (a) joule
   (b) joule
   (c) watt
2. 400 joules (taking g = 10 m/s^2)
3. 125 watts (taking g = 10 m/s^2)
4. 80 m
5. (a) B
   (b) A
   (c) B

Chapter 19

1. *Amoeba, Euglena, Paramecium*
2. sea anemone, jellyfish, bluebottle
3. chiton, periwinkle, limpet, zebra top shell (*Austrocochlea*) (see figure 19.25)
4. oyster, mussel, pipi, scallop, cockle
5. octopus, squid
6. crustaceans, spiders, insects, centipedes, millipedes
7. (a) cockroach, flea, bee, grasshopper, ant, mosquito
   (b) slater, lobster, prawn (*Note:* scorpions and ticks are spiders.)
8. molluscs
9. Both have exoskeletons and jointed limbs.
10. (d)
11. (d)
12. (a)
13. (d)
14. E
15. A
16. D
17. B
18. C

Chapter 20

1. algae
2. spore
3. gamete
4. fungi
5. parasite
6. gymnosperms
7. angiosperms
8. (a)
9. (b)
10. (a)
11. (a)
12. (c)
13. (b)
14. (a)
15. (b)

Chapter 21

1. cocci, bacilli, spirilla
2. bacteria and fungi
3. rotting plant and animal material
4. bacterium
5. by producing antibodies in the blood

6. **(a)** false
   (b) false
   (c) true
   (d) true
7. **(a)** observation
   (b) hypothesis
   (c) hypothesis
   (d) experiment
   (e) experimental result
8. (b)
9. (c)

Chapter 22

1. slow down
2. causes a slowing down, that is, a depression
3. alcohol, tobacco, sedatives
4. The most common reason is to get money to buy more drugs for themselves.
5. (b)
6. (d)
7. Author prefers (b).

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